CHAPTER 4

HEATING SYSTEMS

Learning Objective: Identify the principles and theory of heating and the procedures required for installing, operating, maintaining, troubleshooting, and repairing warm-air heating and hot-water heating systems and associated peripheral equipment.

Heat is one of the prime necessities of life. It is as essential as food, clothing, and shelter. You can have a very good shelter, but you still need heat to be comfortable in it. By studying this chapter, you will start to gain knowledge of what you will be required to know to become efficient in the Utilitiesman (UT) field.

PRINCIPLES OF HEATING

Learning Objective: Understand the basic principles and theory of heat, heat measurement, and heat transfer.

Long after people had advanced to the stage of house building, heating methods had not improved much. For centuries fires for heating and lighting were contained in braziers or confined to an unused corner of a room. The smoke was supposed to escape through a hole left in the roof of the building during construction. Of course, a considerable amount of rain and snow entered the room during bad weather. During the twelfth century, however, the people in the northern part of Europe started using crude fireplaces and flues to replace the brazier and hole-in-the-roof method of heating. Some of these rudimentary heating systems still exist in France.

In the thirteenth and fourteenth centuries, the round, hollow stone chimneys began to be used. At the end of the fourteenth century, people were using a number of fireplaces in their homes and grouping the chimneys together in a vertical, rectangular mass of masonry with decorative effect. By the end of the Italian renaissance period, chimneys were in common use.

During colonial days in America, the fireplace chimneys were a large masonry mass projected through the center of the roof or were an important feature of the gable end walls. This general trend is often followed in architecture today because central heating, required in places where fires are required 5 or 6 months of the year, makes the chimney an important feature of a heating plant. There are heating installations, however, that do not make use of the masonry chimney and have substituted an inconspicuous metal smoke pipe. Other types of heating, such as electrical heating, require no chimney. Methods and equipment used for heating the places we live and work have progressed quickly in the last 100 years. This quick advance is due to our understanding of the principles and theory of heat, which in earlier times was not yet understood.

THEORY OF HEAT

Heat is a form of energy that is known for its effect. Heat can be produced or generated by the combustion of fuels, by friction, by chemical action, and by the resistance offered to the flow of electricity in a circuit. However, the particular form of generated heat with which the heating specialist will be dealing is produced by combustion. Generated heat is obtained by burning common types of fuels, such as coal, oil, and gas.

MEASUREMENT

To operate a heating plant efficiently, you must be familiar with the measurement of heat and how this heat is transferred from the plant to the space being heated. The first part of this section is devoted to measuring temperature; the second part is concerned with the transfer of heat from the plant to the space being heated.

Measurements of temperature and pressure, which are obtained continuously, are very important factors in the operation of a heating plant. The degree of correctness of these measurements directly affects the safety, the efficiency, and the reliability of the operation of the heating plant. Although heat and temperature have a direct relationship, there is also a distinction between them. For example, a burning match develops a much higher temperature than a steam radiator, but the match does not give off enough heat to warm a room. Another example tells us that IO pounds of water at 80°F will melt more ice in a given length of time than 1 pound of water at 100°F. The former has more heat, but the latter has a higher temperature. Temperature is the measurement of heat intensity in degrees Fahrenheit or Celsius. Therefore, temperature measurements can be made by using a glass thermometer calibrated either in degrees Fahrenheit or Celsius. The generally accepted way of stating measurements of temperature in English-speaking countries is in degrees Fahrenheit.

The thermometer measures the degree of sensible heat of different bodies. The thermometer can make a comparison only between the temperature of a body and some definitely known temperature such as the melting point of ice or the boiling point of water. Figure 4-1 shows a comparison of the scales of Fahrenheit and Celsius thermometers. It also shows the marking of the freezing and boiling points of pure water at sea level. The range of the Fahrenheit thermometer between the freezing point and the boiling point is 180° (32° to 212° = 180°). On the Celsius thermometer, the range is 100° (0° to 100° = 100°) from the freezing point to the boiling point.

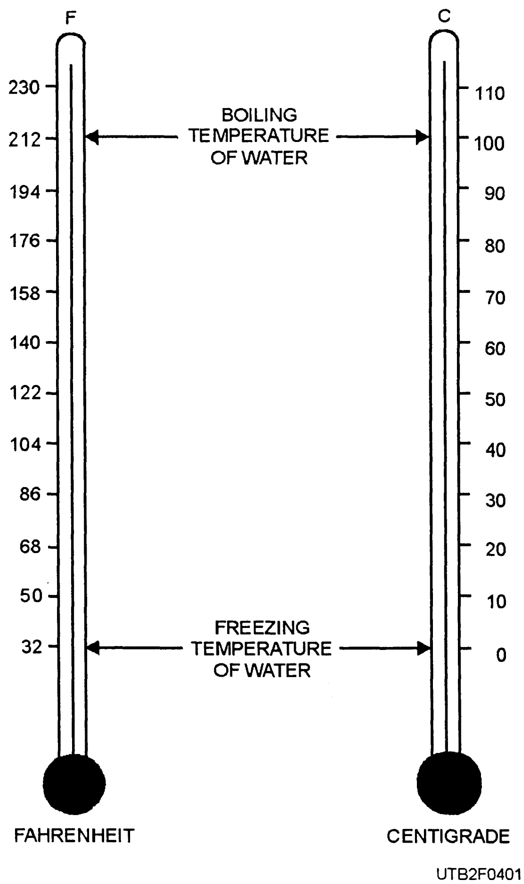

Figure 4-1.—Comparison of Fahrenheit and Celsius thermometers.

To convert Fahrenheit readings to Celsius:

(°F - 32°) ÷ 1.8 = °C

To convert Celsius readings to Fahrenheit:

(°C x 1.8) + 32° = °F

The heat that can be measured by a thermometer and sensed or felt is referred to as "sensible heat." An example of sensible heat is presented by placing a small vessel of cold water over a gas flame and putting a thermometer in the water. Upon observation, you note that the thermometer indicates a rise in temperature. Also, if you place your finger in the water several times, you will feel (or sense) the change in temperature that has taken place.

The unit of measurement for a given quantity of heat is the British thermal unit, abbreviated and commonly known as Btu. One Btu is the amount of heat needed to change the temperature of 1 pound of water 1° Fahrenheit at sea level. If one Btu is added to 1 pound at 50°F, the temperature of that pound of water will be raised to 51°F.

All substances above absolute zero contain heat. There is heat even in ice, and its melting point is fixed at 32°F. Because of a fundamental law of nature, when ice at 32°F melts into water at 32°F, a change of state takes place. The ice (solid) has turned into water (liquid). A certain amount of heat is required during this change of state. This heat is known as latent heat. Latent heat is the amount of heat required to change the state of a substance without a measurable change in temperature.

There are other types of heat that you will encounter in heating. These are as follows:

- Specific heat–The ratio between the quantity of heat required to raise 1 pound of any substance 1°F and the amount of heat required to raise the temperature of 1 pound of water 1°F.
- Superheat–The amount of heat added to a substance above its boiling point.
- Total heat–Is the sum of sensible heat plus latent heat.

We previously mentioned absolute zero. But, what is absolute zero? Scientists have determined that when the temperature of a substance has been reduced to -460°F that all the heat has been removed from a substance. At this point all the molecules cease to have motion. Absolute zero is the lowest temperature obtainable. Heat is present in all substances when the temperature is above absolute zero.

HEAT TRANSFER

The transfer of heat is the next problem to consider after the heat has been produced. It must be moved to the space where it is to be used. Heat always flows from a warmer to a cooler substance; consequently, there must be a temperature difference before heat can flow. Naturally, the greater the temperature difference, the faster the heat flow. Two objects that have different temperatures, when placed together, tend to equalize their temperature. Heat travels in heating systems from one place to another by three different methods. All three of these methods are used in most heating systems. They are discussed in the paragraphs that follow

Conduction

Conduction is the flow of heat from one part of a substance to another part of the same substance or from one substance to another when they are in direct contact.

When one end of a stove poker is held in a flame, the other end will soon be too hot to hold. This indicates that the heat is being conducted, or transferred, from one end of the poker to the other end. Such a transfer of heat is called conduction. Conduction is used to transfer heat through the walls of a stove, furnace, or radiator so that the warmth can be used for heating. Some materials do not conduct heat as well as others. For example, if a piece of wood had been used instead of the poker, the end of the wood away from the fire would have remained cool. Those materials that offer considerable resistance to heat flow are referred to as insulators or poor conductors.

Convection

Convection is the transfer of heat by means of mediums, such as water, air, and steam. When air is heated, it expands, becomes lighter in weight, and rises. The cooler air, which is heavier, then flows in to replace the warm air. Thus a convection current is set up. Water, when heated, acts in the same way as air. The water next to the heating surface becomes warmer, lighter, and rises. This action allows the cooler water to flow in next to the heating surface and become heated. Convection is a very important factor in a heating system. It is this force, developed by heating the medium, which circulates that medium to the space to be heated.

Radiation

Radiation is the transfer of heat through space. When a hand is held in front of a stove, it is quickly warmed by means of radiation. In this same manner, the earth receives its heat from the sun.

Radiated heat is transferred by heat waves, similar to radio waves. Heat waves do not warm the air through which they pass, but they must be absorbed by some substance to produce heat. For example, when you stand in the shade of a tree, you feel cool because the leaves and limbs are absorbing the heat waves before they reach you.

When heat waves strike an object, some are reflected, some may pass through, and the object absorbs the rest. Polished metals are the best reflectors known; therefore, they are a poor absorber of heat. A poor absorber is also a good radiator. Rough metal absorbs heat more readily than a highly polished metal, and it also loses heat faster by radiation.

The color of a substance also affects its absorbing power. A black surface absorbs heat faster than a white one. That is why light-colored clothes are cooler in summer than are dark-colored clothes.

Q1. Heat can be produced or generated by what methods?

Q2. What two types of measurements directly affect the safety, efficiency, and reliability of heat plant operations?

Q3. Temperature is the measurement of what?

Q4. Convert 82 degrees Fahrenheit to degrees Celsius.

Q5. Heat travels in heating systems by what three methods?

COMBUSTIBLE FUELS

Learning Objective: Understand the types and characteristics of combustible gases and fuel oils used in heating systems.

If electricity and coal are disregarded, the fuels most commonly used with heating equipment are either gas or petroleum. Next, we will take a brief look at the types and characteristics of combustible gases and fuel oils used for heating.

TYPES OF GASES

Gaseous fuels are usually classified according to their source that, in turn, determines their chemical composition. The heat valve (Btu per cubic foot) varies with the types of gas and determines the quantity required for a specific heating requirement. The types principally in use are natural gas, manufactured gas, and liquid petroleum gas (table G, appendix II).

Natural Gas

Natural gas is a mixture of combustible gases and usually small amounts of inert gases obtained from geologic formations. While the composition of natural gas varies with the source, methane (CH_4) is always the major constituent. Most natural gases also contain some ethane (C_2H_6) along with small amounts of nitrogen and carbon dioxide (CO_2). Natural gas is colorless and odorless in its natural form; however; a distinctive odor is usually added as a safety factor for detecting leaks. Natural gas mixes readily and completely with combustion air and thus is substantially free from ash and practically smokeless. These characteristics contribute to good environmental pollution control. From a standpoint of trouble-free performance, ease of handling, and control, natural gas offers many advantages that make it the most desirable of all heating fuels.

Manufactured Gas

The common manufactured gases are carbureted water gas, oil gas, and producer gas. These gases are roughly one-half hydrogen and one-third methane, plus small amounts of carbon dioxide, nitrogen, and oxygen. They are made by converting low-grade liquid or solid fuels to the gaseous form by destructive distillation (cracking) of oil or coal, by the steam-carbon reaction, or by a combination of both processes. These gases are ordinarily used at or near the production point because of high manufacturing costs rule out the added expense of distribution.

Liquefied Petroleum Gas

Liquefied petroleum gases are hydrocarbon gases normally obtained as a by-product of oil refineries or by stripping natural gas. These compounds are normally gaseous under atmospheric conditions; however, they can be liquefied by moderate pressure at normal temperatures.

The principal LPG products are propane (C_3H_8) and butane (C_4H_{10}). Propane, the most common, is available by the bottle or cylinder and in bulk form. Its boiling point is -44°F (note that this is very close to that of refrigerant R-22).

Butane is generally available in bulk form. It boils or vaporizes at 32°F. In other words, if the temperature of butane is 32°F or lower, at atmospheric pressure, it remains a liquid, and heat must be applied to bring it to the gaseous state. Note in table G, appendix II, the high heating. values of propane and butane.

Fuel Oils

Fuel oils are derived from crude oil, which consists primarily of compounds of hydrogen and carbon (hydrocarbons), and smaller amounts of oxygen, nitrogen, and depending on the source, sulfur. Practically all fuel oil is either a product or a by-product of refining crude oil by the fractional distillation process or by cracking.

The Bureau of Standards, United States Department of Commerce, standardizes commercially used fuel oils. The oils are numbered in grades 1, 2, 4, 5, and 6 and are titled commercial standard grades (CSG). These grades are identified in the Navy by military specifications and are intended for use in oil-burning equipment for the generation of heat in furnaces for heating buildings, for the generation of steam, and for other purposes. A more in-depth discussion of fuels and their characteristics is contained in *Fundamentals of Petroleum,* NAVEDTRA 10883. A comparison of fuel oils by grade is given in table H, appendix II.

Q6. What are the principal types of gases used in heating?

Q7. Fuel oils consist primarily of what compounds?

WARM-AIR HEATING EQUIPMENT

Learning Objective: Identify the different types of warm-air heating units and equipment and basic installation and maintenance guidelines.

Advances in the field of warm-air heating have made it one of the most popular and widespread forms of heating in use today. It has the advantage of adaptability with various fuels and can be used in a variety of buildings, including barracks, hangars, personnel housing, schools, and theaters. It is likely, therefore, that at one time or another you will be responsible for performing technical maintenance and repair and installation of warm-air heating equipment and systems.

The different types of heating equipment that will be discussed include unit heaters, electric and gas- and oil-fired space heaters, and gas-fired and oil-fired furnaces.

UNIT HEATERS

In this manual the term *unit heater is* defined as an installed equipment item and a component of a system consisting of an extended finned heat transfer surface (coil) and a propeller or blower fan to create airflow through it. Unit heaters are indirect units that differ from space heaters because they generate heat indirectly from a medium of steam or hot water piped through a central distribution system. Space heaters are direct-fired units that generate heat directly by the use of an electrical coil or by a combustible fuel.

Unit heaters can be used for many heating requirements, the major limiting factor being the availability of a steam or hot-water system. They are commonly used with heating systems in shops, offices, dining halls, and warehouses. There are three basic types: (1) the suspended horizontal discharge, (2) the suspended vertical discharge, and (3) the floor-mounted or horizontal type of blower unit (fig. 4-2).

The units are rated in Btu or equivalent direct radiation heat output and cubic feet per minute air discharge capacity at a given fan or motor speed. These ratings are important in the application of unit heaters.

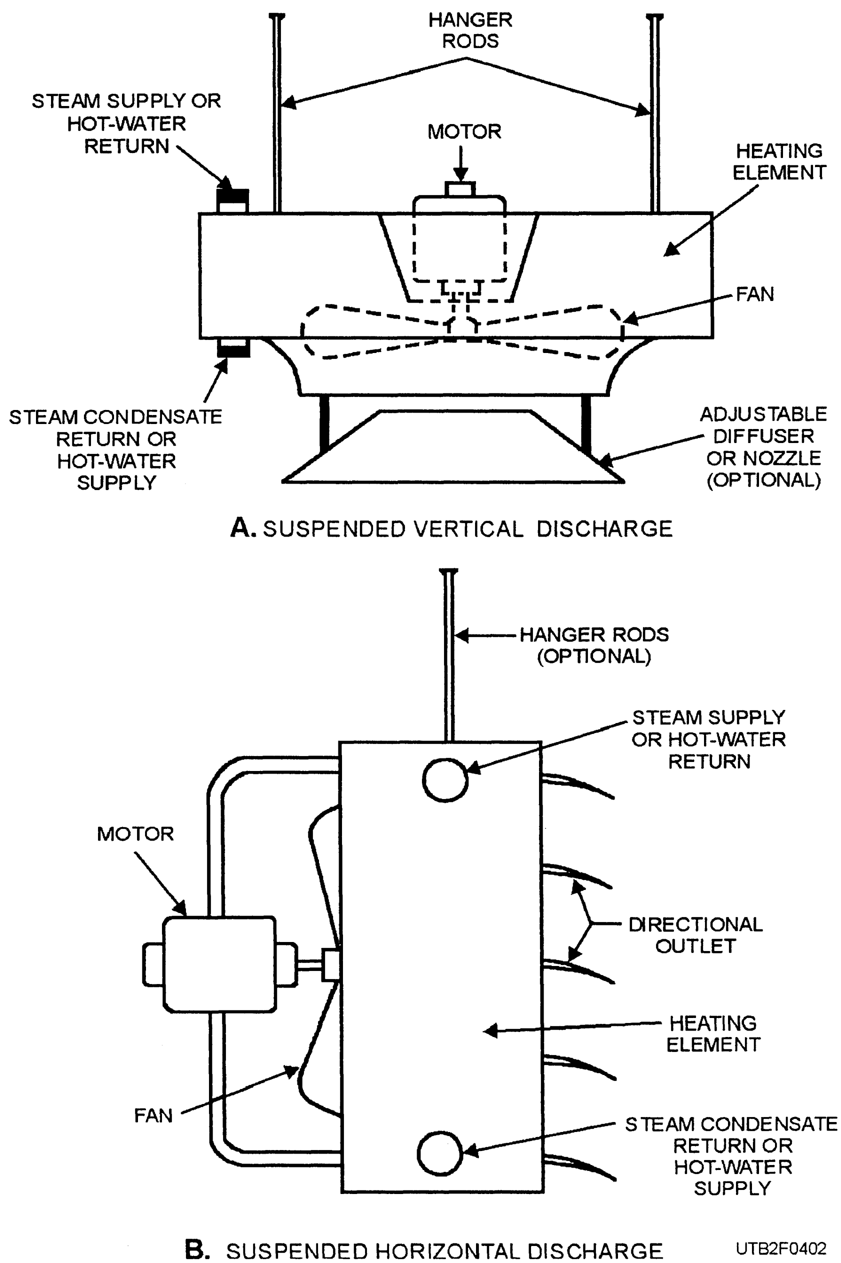

Figure 4-2.—Unit heaters: A. Suspended vertical discharge; B. Suspended horizontal disc harge.

Manufacturers furnish information regarding the area effectively heated by units to enable proper planning and location of the units. Generally, units under 50,000 Btu per hour are designated to operate on low-pressure steam or high-temperature hot water.

Space Heaters

Space heaters are used for heating rooms and similarly enclosed spaces, either in addition to, or in place of, a central heating system. They are desirable as a means of providing heat to a small space because of their simplicity of construction, low initial cost, and reasonable fuel consumption. They may be placed directly in the space or at such a location where heat can be delivered through a single register into the space.

Space heaters are sometimes classified by the manner in which they transfer heat to the space to be heated; for example, by radiation and/or convection. The terms *direct-fired* and *indirect-fired* are also used to identify such heaters. In this manual, space heaters are identified as direct-fired units and by their heat source or fuel. This discussion will include electric, gas-fired, coal-fired, and oil-fired units.

Electric Heaters and Installation

Space heaters with electrically powered heating elements are used in spaces where it is desired to eliminate cold spots and maintain uniform temperatures, where other fuels are useful as portable units on the floor to overcome floor drafts, and as fixed units mounted in, or to walls or ceilings. They are generally rated in kilowatts (kW). One kW (1,000 watts) is equal to 3,415 Btu per hour.

Electric space heaters are available in two general types—the radiant and natural convection type and the forced warm-air (fan) type. In the radiant and natural convection type, heat from electric elements rises and strikes parabolic (bowl-shaped) reflectors. The reflectors are highly polished curved metal surfaces, which deflect the heat outward into the place where heat is desired (fig. 4-3). Some radiant heat units have no deflectors but provide a combination of radiant and natural convection heat, which rises from the coils into a chamber open on the side where heat is required. The electric baseboard convection heater is an example of this type. The forced warm-air type uses a motorized fan to circulate heat from the heating element outward into the space (fig. 4-4). The electric units are operated manually with an ON-OFF switch or automatically with a thermostat.

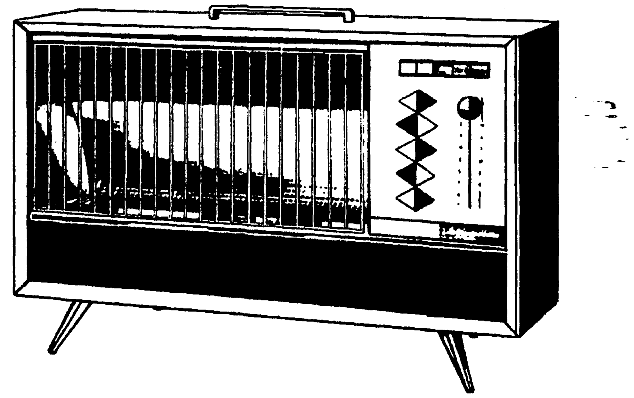

Figure 4-3.—Radiant electric space heater.

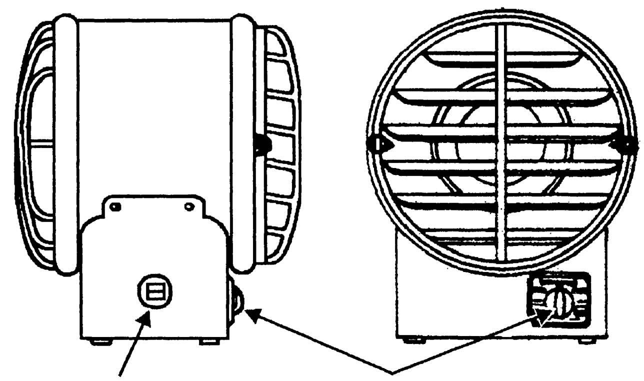

Figure 4-4.—Forced warm-air electric space heater.

In the selection and installation of electrical space heaters, safety must be assured. Units that are to be installed should bear the label of the Underwriter's Laboratories (UL). They should also conform to the safety standards outlined in space heating equipment UL-573. All electrical work required for an installation should be done according to the manufacturer's instructions and by a qualified electrician.

Gas Heaters and Installation

Gas-fired space heaters are clean in operation; they are easily operated and require no fuel handling. They are adaptable for use with natural gas, manufactured gas, or liquefied petroleum gas. Their construction features are similar regardless of the type of gas used. Basically, there are two types—the vented and the unvented.

VENTED UNITS are enclosed metal cabinets with either top and bottom or front and rear grilles for warm-air circulation. The flame burns in a closed combustion chamber, and the heater vent carries away the gases (fig. 4-5). The flow of heat is maintained by a motor-driven fan and is controlled by vanes, fins, louvers, or diffusers. This type of unit is more satisfactory than the unvented type because there is less danger of carbon monoxide poisoning. A panel unit is one type of vented unit (fig. 4-6). It may be recessed or surface-mounted in either an interior or exterior wall with a vent properly insulated and run up

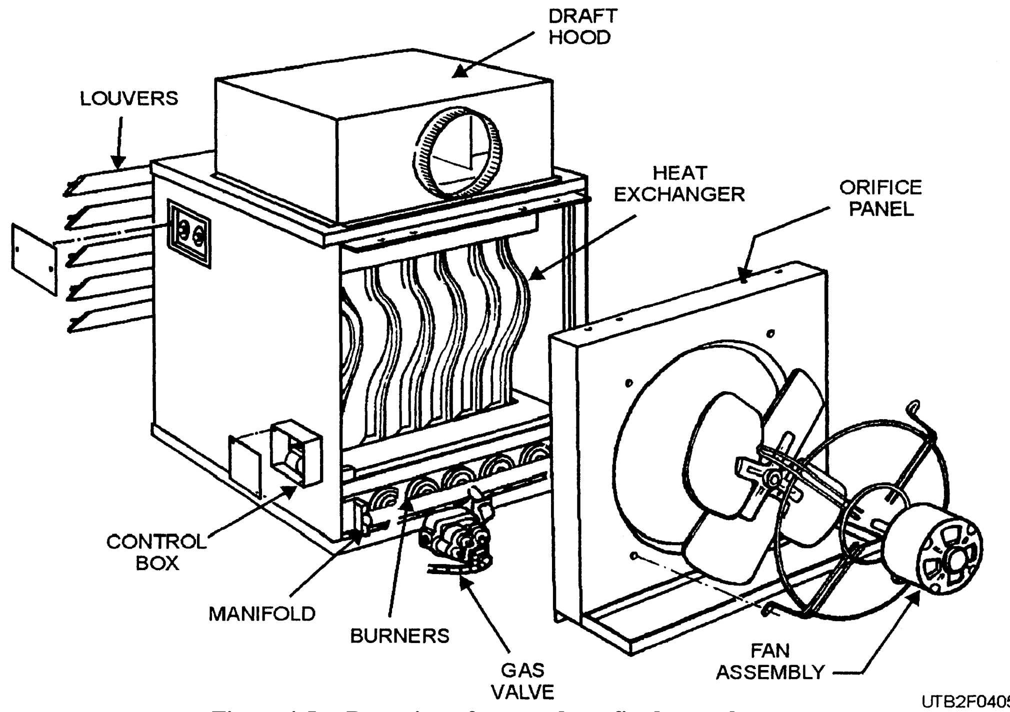

Figure 4-5.—Rear view of a vented gas-fired space heater.

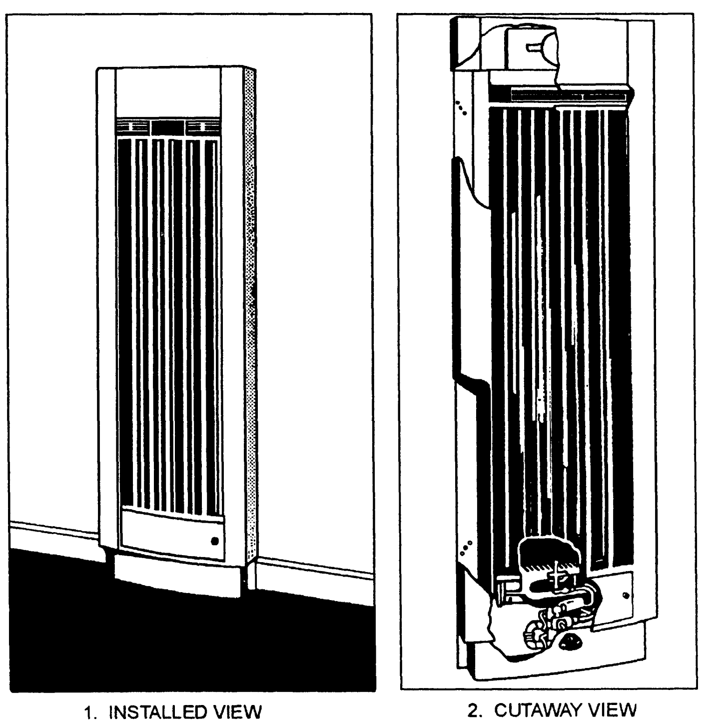

Figure 4-6.—Gas-fired panel space heaters.

through the wall. This type of unit has the advantage of requiring less floor or ceiling space.

UNVENTED UNITS are usually the open-flame type where the gas burns in an open combustion chamber. These heaters should be used in a well-ventilated area. Ventilation ensures that the carbon monoxide produced by the gas flame is removed.

Gas-fired space heaters and their connections must be of the type approved by the American Gas Association (AGA). They must also be installed according to AGA specifications. Installation factors, such as the type of gas, the capacity of the heater, and the line pressure drops, must be known to ensure proper plumbing procedures with respect to the gas service line. All newly installed piping should be tested for gas leaks. These tests should comply with NAVFAC DM3.

On vented gas units, be careful to install the venting system properly to minimize the harmful effects of condensation and to ensure that the combustion products are carried away. During operat ion, the inner surface of the vent must be heated above the dew point of the combustion products. This prevents water from forming in the flue pipe. Vent sections must be installed with the male ends of the inner liner down to allow any condensation that forms to return. This is important since the burning of 1,000 cubic feet of natural gas produces approximately 12 gallons of water. For the same reason, horizontal flue pipes should have an upward pitch of at least 1-inch per running foot.

Vent pipes should be equipped with draft diverters. A diverter is a type of inverted cone through which the flue gases must pass on their way to discharge. It allows air from the heated room to be drawn into the flue pipe joining the combustion-gases. This action prevents excessive downdrafts or updrafts that are apt to extinguish the pilot light or possibly the main burner.

Oil-Fired Space Heaters

In areas where oil is the principal fuel, oil-fired space heaters are used for many space heating requirements. Oil-fired space heaters are very simple in construction. They consist of a burner, a combustion chamber and outer casing, a fuel tank, and fuel control valve. An air space is provided between the combustion chamber and the outer casing. Air enters through grilles in the bottom of the heater, is heated, and passes out through grilles in the top of the unit. Some oil-burning heaters are equipped with a blower and electric motor to force the heated air out into the room. They turn at slow speed and may be either direct drive or belt driven.

Oil-fired space heaters have atmospheric vaporizing-type burners. The burners require a light grade of fuel oil that vaporizes readily at low temperatures and leaves only small amounts of carbon and ash. Number 1 fuel oil is generally used. The two types of burners that will be discussed are the natural draft pot and the perforated sleeve.

NATURAL DRAFT POT DISTILLATE BURNERS are widely used for space heaters, room heaters, and water heaters. A cutaway view of a natural draft pot type of burner is shown in figure 4-7. In operation, the distillate (oil) is fed at the bottom of the burner, either at the center or on the sides, and is

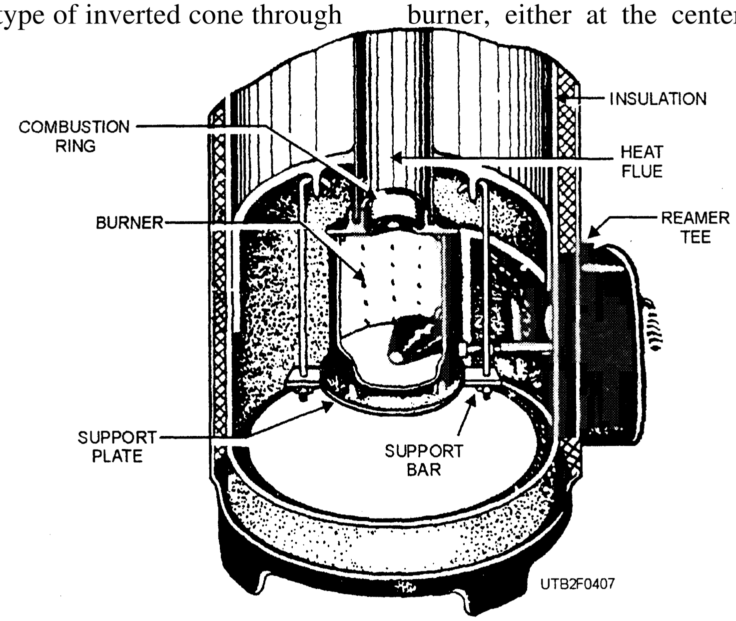

Figure 4-7.—Cutaway view of a natural draft pot type of burner.

vaporized at this point by radiant heat from above. The vapors rise and mix with the air drawn through the perforated holes in the burner. During high fire conditions, the flame burns above the top combustion ring, as shown in figure 4-8; and under low fire conditions, the flame burns in the lower portion or pilot ring of the burner, as shown in figure 4-9.

The PERFORATED SLEEVE BURNER consists of a metal base formed of two or more circular fuel vaporizing grooves and alternate air channels (fig. 4-10). Several pairs of perforated sleeves or cylinders force the air through the perforations into the oil vapor chamber. In this way a large number of jets of air are introduced into the oil vapor, bringing about a good mixture. This mixture burns with a blue flame and is clean and odorless.

These burners usually have a short kindling wick. Some burners have a cup below the base in which alcohol is burned to provide heat for starting. The wick and alcohol are used only for lighting.

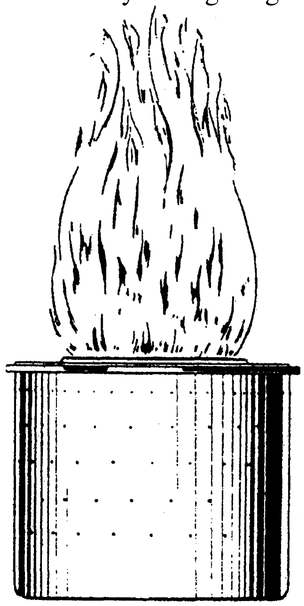

Figure 4-8.—High fire flame.

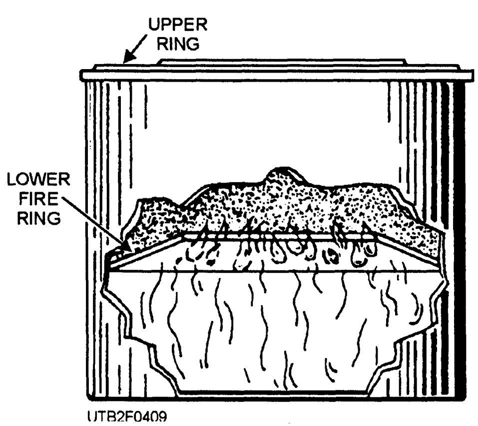

Figure 4-9.—Low fire flame.

Installation

Oil-burning heaters are portable and are easily moved from one location to another. For satisfactory operation, follow the installation procedures supplied by the manufacturer. In both pot type and perforated sleeve burners, oil is fed to the burner under control of a float-operated metering valve (fig. 4-11). Set the unit level so the oil can be properly distributed in the burner.

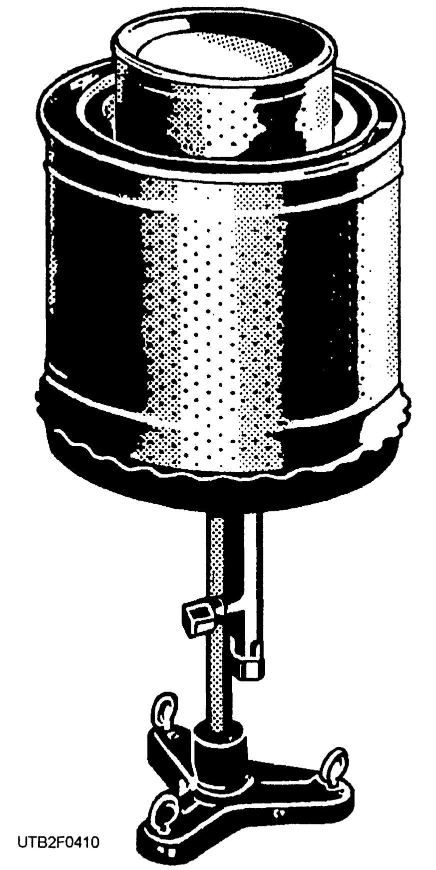

Figure 4-10.—Perforated sleeve burner.

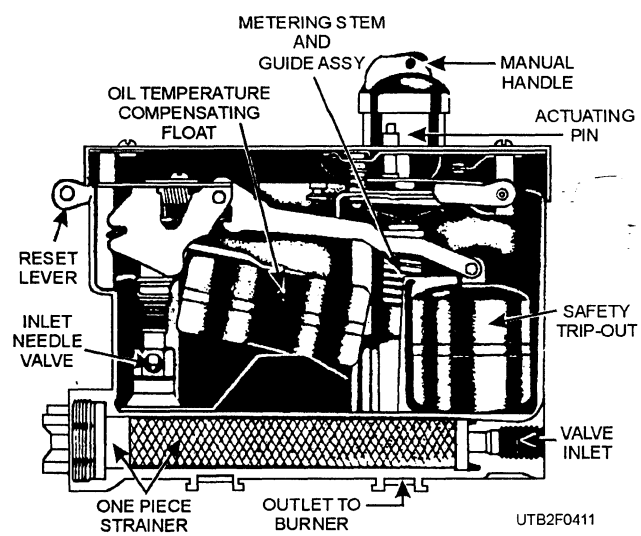

Figure 4-11.—Oil-controlled metering valve.

NOTE

The fuel level control valve is the only safety device on the oil-fired space heater.

When several space heaters are installed in a building, an oil supply from an OUTSIDE TANK to all of the heaters is often desirable. This eliminates frequent filling of individual tanks and reduces waste from spilling. Figure 4-12 shows the principal elements of such a system and important points to consider during installation.

Be sure that the space heater is placed a safe distance from the wall. You also need a metal pan for it to sit in. This pan catches the oil if a leak occurs. Do not use a sandbox or cement as both absorb oil and create a fire hazard. In case of wood floors, place a piece of fire-retardant material, such as Gypsum board (Sheetrock) on the floor underneath the metal pan. It may also be needed on the wall behind the heater if the wall is made of wood.

Since the flow of air to a vaporizing type of burner is induced by a chimney DRAFT, pay careful attention to this feature. The draft produced by any chimney depends upon the height of the chimney and the difference in temperature between the flue gas and outside air. The cross-sectional area required depends upon the volume of flue gas to be carried. Since outside air temperature varies during the heating season, arrange the chimney or flue to produce the necessary draft under the most unfavorable conditions likely to be encountered, usually an outside temperature of 60°F. Above this temperature, heat is not usually required, and below this temperature, draft would be increased.

Install the draft REGULATOR to maintain a constant draft adjustment for the rate at which the heaters are fired. The regulator is a swinging damper or gate with provision for adjustment. Since balance and free action are the fundamentals on which its operation depends, be sure the installation provides for these features. Install the damper section with the word *top* at the true top position. Make sure the face is plumb. When the damper regulator is installed in a horizontal run of pipe, do not use a counterweight on the damper.

A DOWNDRAFT may seriously interfere with proper functioning of these burners. Downdraft may result when the chimney is not high enough above the roof line or is too close to other high buildings, trees, or terrain features. The chimney top must be at least 3 feet above the highest point of the building roof. If the difficulty is caused by other factors, a downdraft hood may prove effective. There are several successful designs; a simple constructed type is shown in figure 4-13.

Copper tubing is often used in an oil supply system to burners because of its high resistance to corrosion and ease of installation. The use of compression fittings or flair fittings is best for fuel supply applications. A major advantage in using copper tubing is that it can be bent easily without collapsing the tube, especially if a tubing bender is used; this cuts down on the number of fittings required for installation.

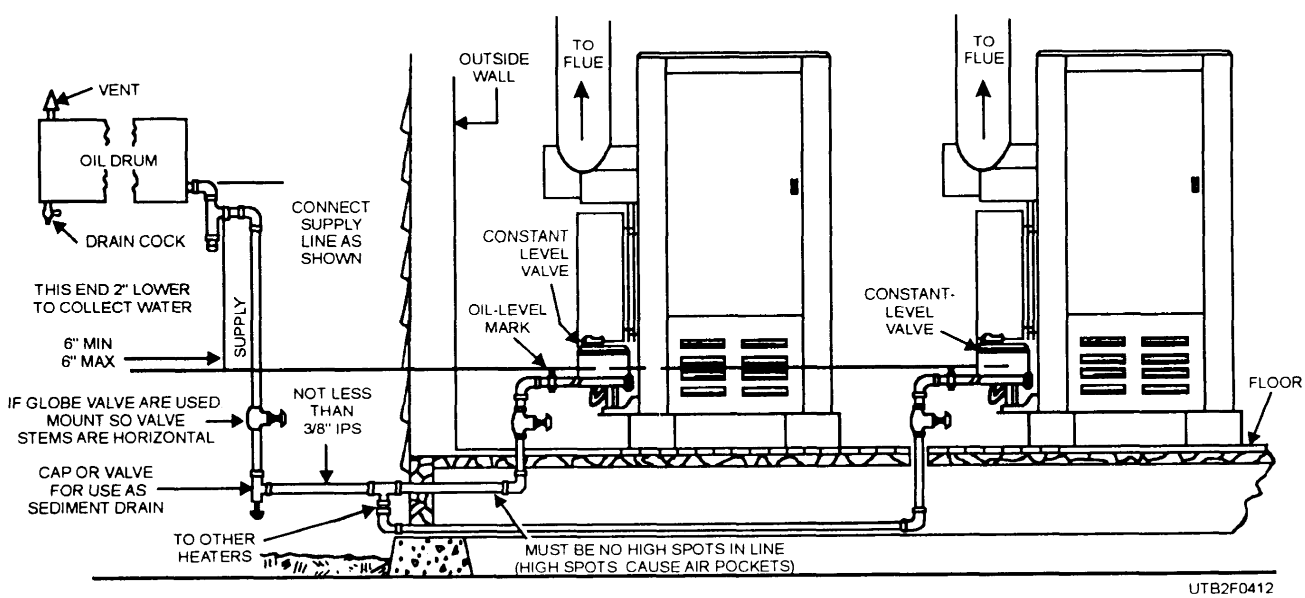

Figure 4-12.—Space heaters installed in series.

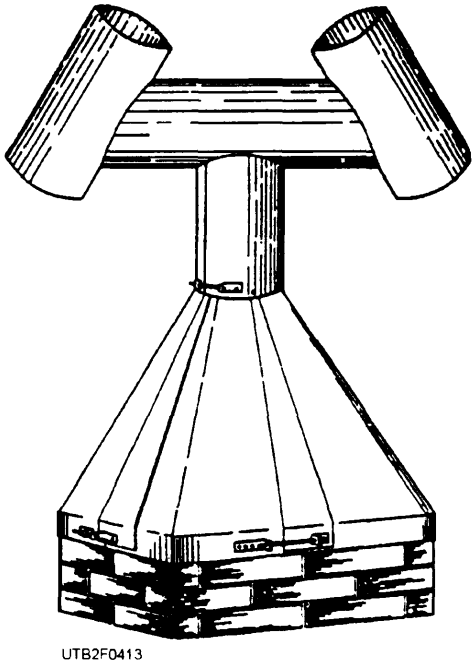

Figure 4-13.—H-type downdraft hood.

UNIT HEATER MAINTENANCE

Oil-fired space heaters require periodic cleaning. Frequent checks must be made to ensure that equipment is kept clean, because accumulations of carbon and soot can cause disastrous fires. Units should be moved when they are cleaned, so they can be cleaned inside and out. Accumulations of soot must be removed from inside the fuel pipe. All piping and tubing should be kept clean and free of oil drippings.

The pot or burner assembly may be cleaned without removing the heater. When cleaning this component, remove it through the front door opening and clean all the air holes using a soft copper wire. Do not remove all the carbon from the bottom, because a small accumulation of carbon at the bottom acts as a wick and helps maintain the pilot light. In replacing the burner assembly, make sure both sides of the burner are tightened equally, so the top of the burner and the fire-retardant gasket are set firmly against the flue projection.

In checking the constant-level control valve, check the operation of the heater through a complete cycle of operation from the pilot fire position to the main fire position, and then back to the pilot fire position. Set the control valve, if it is the manual type, to high fire; and if equipped with a thermostatic device, set the thermostat above room temperature. If the heater fails to operate properly through the cycle, check the constant-level control valve and follow the manufacturer's instructions for disassembly and cleaning. A parts breakdown of the valve is shown in figure 4-14.

Some of the common problems with pot and sleeve oil burners, gas-fired space heaters, their causes, and possible remedies are listed in appendix II, tables I and gentlemen.

Q8. What are the basic types of unit heaters?

Q9. How are electrically powered space heaters generally rated?

Q10. When you select and install an electric space heater, what factor should be paramount?

Q11. On vented gas-fired space heaters, it is important to install the venting system properly to minimize the effects of what problem?

Q12. What type of burner is used in an oil-fired space heater?

Q13. What is the only safety device on an oil-fired space heater?

Q14. To maintain a constant draft for the burner of an oil-fired space heater, what device should you install in the chimney?

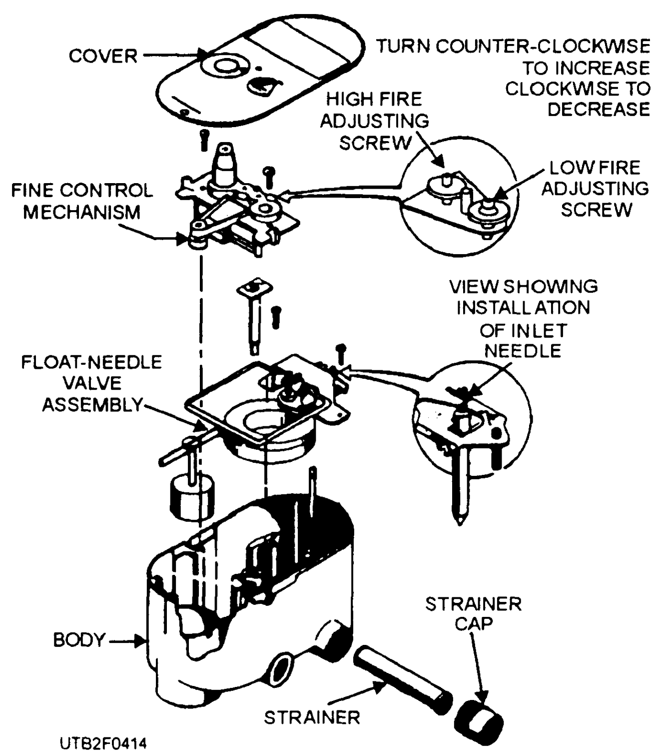

Figure 4-14.—Constant-level control valve.

WARM-AIR HEATING SYSTEMS

Learning Objective: Identify the different types of warm-air systems, gas-fired and oil-fired furnaces, components, controls, and the procedures for installation, operation, and maintenance.

Heating equipment for complete air-conditioning systems is classified according to the type of fuel burned, the Btu capacity of the furnace, and the method of circulating the warm air. Warm-air systems are generally identified as either a gravity-type or a forced-air type system.

GRAVITY SYSTEM

Gravity furnaces are often installed at floor level. These are really oversized, jacketed space heaters. The most common difficulty experienced with this type of furnace is a return-air opening of insufficient size at the floor. Make the return-air opening on two or three sides of the furnace wherever possible. Provide heat insulation above the furnace top to avoid a possible fire hazard.

Gravity warm-air heating systems operate because of the difference in specific gravity (weight) of warm air and cold air. Warm air is lighter than cold air and rises when cold air is available to replace it.

FORCED-AIR SYSTEM

The majority of the furnaces produced today are of the forced warm-air type. This type of furnace includes the elements of a gravity warm-air system plus a fan to ensure adequate air distribution. It may include filters and a humidifier to add moisture to the air. The inclusion of a positive pressure fan makes possible the use of smaller ducts and the extension of the system to heat larger areas without the need for sloping ducts. It is possible to heat rooms located on floors below the furnace if necessary. Forced-air furnaces are manufactured in a variety of designs. A typical oil-fired furnace is shown in figures 4-15 and 4-16. A typical gas-fired furnace is shown in figure 4-17.

In a forced-air system, the fan or blower is turned on and off by a blower control which is actuated by the air temperature in the bonnet or plenum. The plenum is

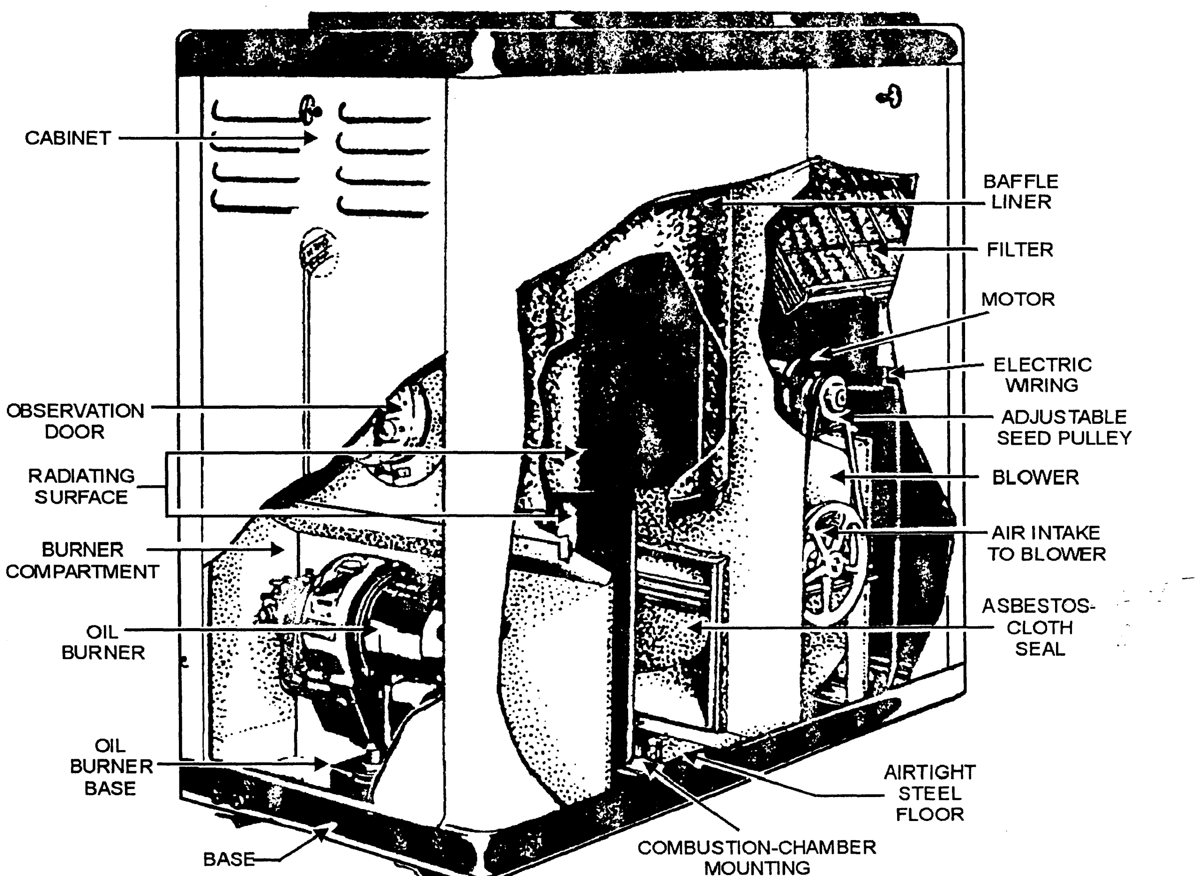

Figure 4-15.—Cutaway view of a typical oil-designed furnace.

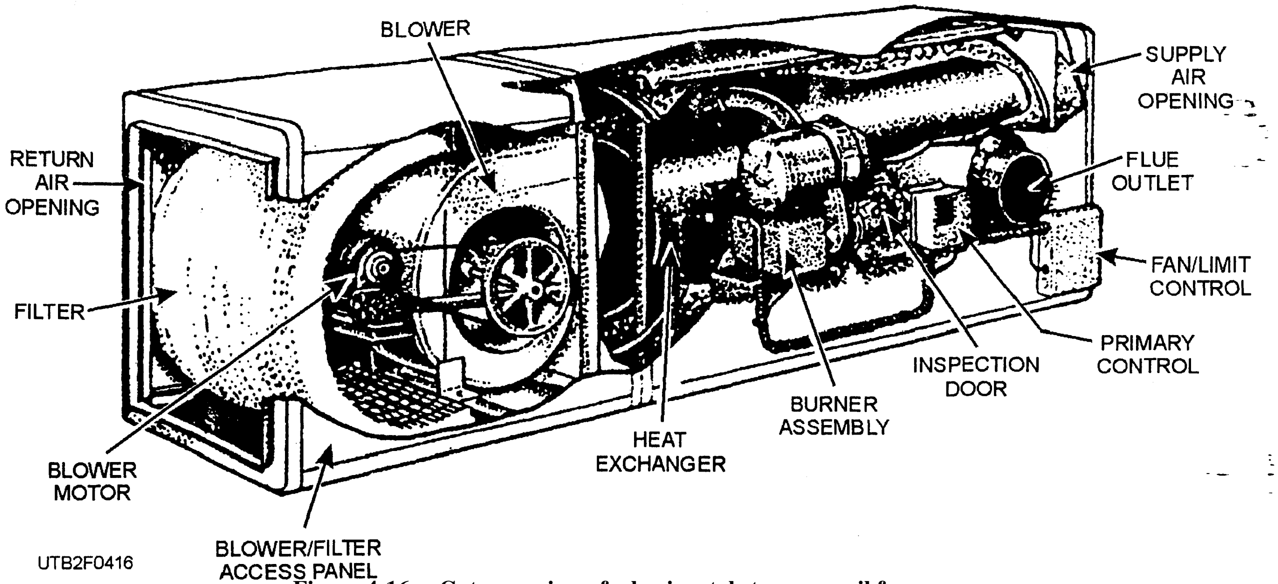

Figure 4-16.—Cutaway view of a horizontal stowaway oil furnace.

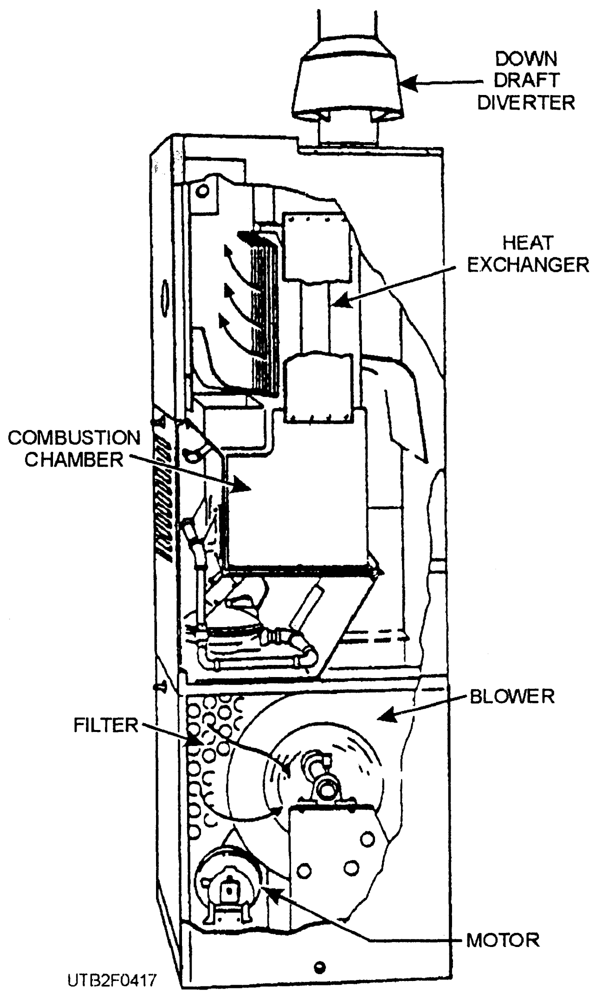

Figure 4-17.—Gas-fired vertical warm-air furnace.

that part of the furnace where it joins the main trunk duct (fig. 4-18). The blower control starts the fan or blower when the temperature of the heated air rises to a set value and turns the fan or blower off when the temperature drops to a predetermined point. Thus the blower only circulates air of the proper temperature.

AIR DISTRIBUTION

A knowledge of air distribution principles is important when dealing with central warm-air heating systems. Satisfactory heating from warm-air systems is absolutely dependent upon proper distribution of warm air from the heat source to all portions of the space served. Warm air must be distributed in quantities that are required to offset the rate of heat released to each room. With radiator systems, distribution is primarily a problem of getting enough hot water or steam to each radiator to be sure the radiator heats to its rated capacity. It is not possible to deliver more heat through steam or hot water than the radiator is designed to transmit. With warm-air systems, however, the rate of air delivery and the temperature of the air delivered to the room determine the amount of heat reaching each room. Temperature balance, therefore, is primarily a problem of controlling air distribution.

Factors, such as velocity, volume, temperature, and airflow direction, play an important part in temperature balance. In addition and for human comfort, space-temperature variations and noise levels must also be considered. Convection currents result from the natural tendency of warm air to rise and cold air to fall. Examples are the temperature variations near doors and windows, and when dense, cool air is drawn away quicker than warm air. Objectionable noise will result at supply diffusers if room velocities exceed 25 to 35 feet per minute (fpm). Air stratification and cold floors may also result when supply diffusers are not properly located within the space.

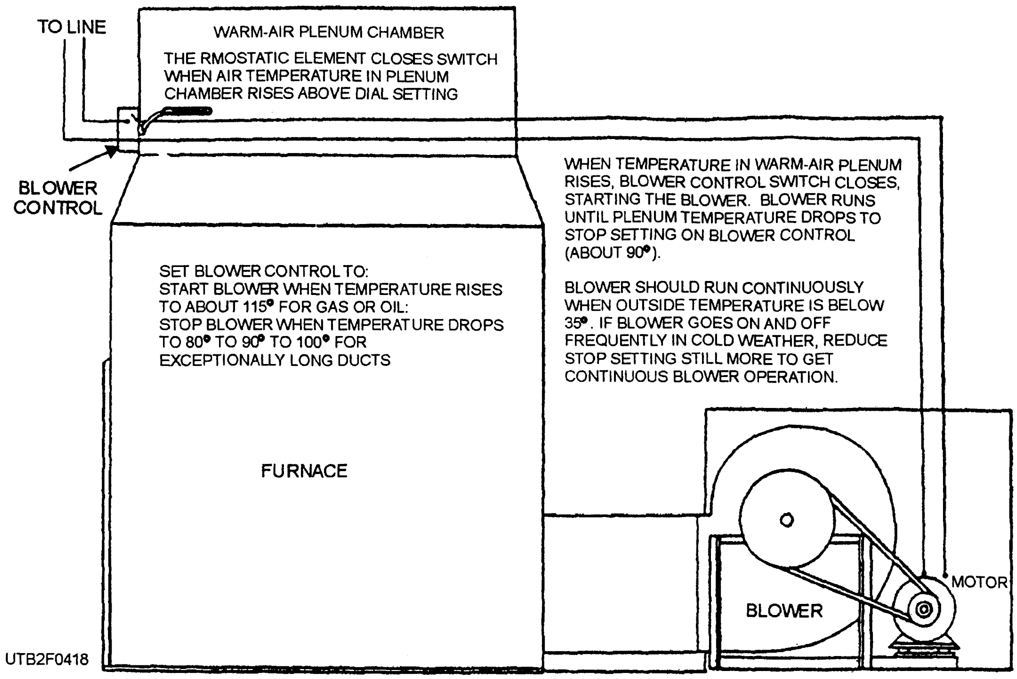

Figure 4-18.—Electrical circuit showing how blower control operates blower motor when temperature in plenum rises.

Patterns of air distribution vary with the positions of supply diffusers. A diffuser that discharges through the floor in an upward direction or downward through the ceiling provides a vertical distribution of air. On the other hand, a diffuser that discharges through a wall provides a horizontal distribution of air. The spread for either the horizontal or the vertical pattern depends on the setting of the diffuser vanes. A low horizontal discharge provides the most effective distribution Airdistribution that results from different diffuser locations is shown in figure 4-19.

As previously mentioned, warm-air heating systems are generally identified as either the GRAVITY TYPE or the FORCED-AIR TYPE. The type of duct distribution used further identifies these installations. There are two

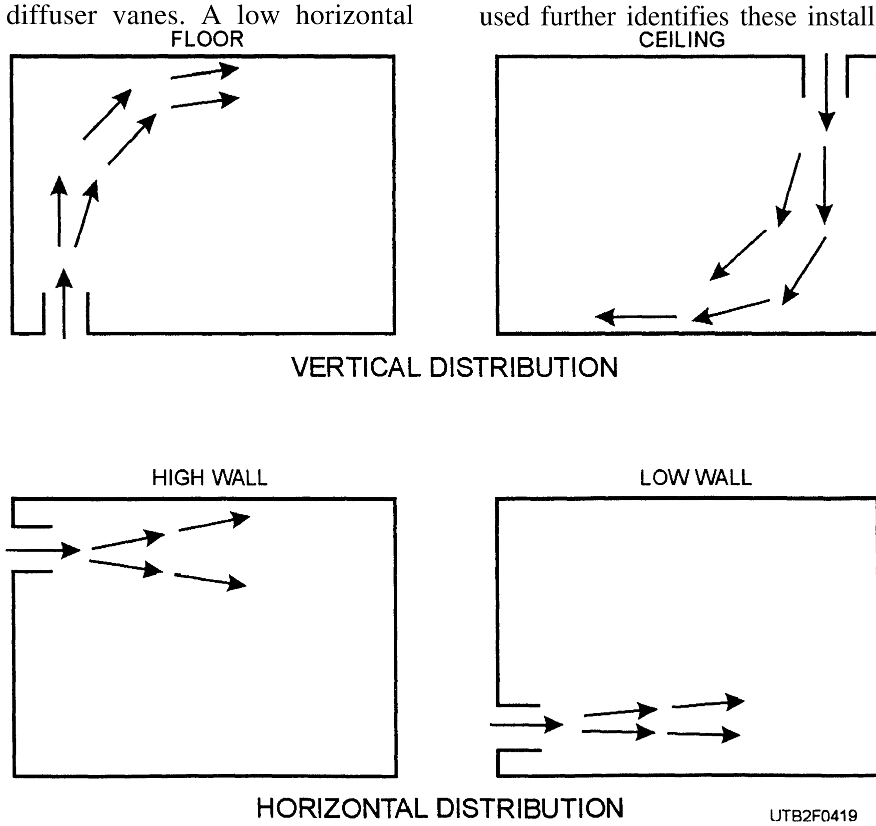

Figure 4-19.—Air diffuser distribution.

types of duct layouts: (1) the INDIVIDUAL DUCT, where each duct is connected directly to the furnace plenum, and (2) the TRUNK AND BRANCH DUCT, where the trunk duct connects to the furnace plenum and then branches off to the outlets. These two types are shown in figures 4-20 and 4-21.

Gravity-type furnaces are rated in leader area capacity, the LEADERS being the warm-air pipes. With respect to return ducts, the register-free area and the return-air duct should not be less than 1 1/4 times the area of the leader serving a given area. Gravity-type installations, as shown in figure 4-21, use the individual duct layout.

Forced warm-air systems usually have a register temperature range of 150°F to 180°F. Ducts can be in the form of a trunk with branches or with individual leaders from a plenum chamber. Furnaces used with forced-air installations must be equipped with automatic firing devices. Velocities usually are in the range of 750 to 900 fpm in trunks and approximately 600 fpm in branches. Outlet velocities at registers may be as high as 350 fpm.

GAS-FIRED FURNACES

In this section, construction features, basic components, gas burners, and controls of gas-fired furnaces are discussed.

Construction Features

The various gas-fired furnaces available today have similar basic components; however, there, are variations in design with respect only to dimensions and airflow. Unit features pertinent to dimensions and airflow are important when selecting a furnace for a particular space or application. A vertical counter-flow unit, for example, is normally used where supply ducts are located beneath the floor, because it has the return in the top and the outlet in the bottom. The most commonly used unit is the UPFLOW HIGHBOY which, as a rule, draws air from the side or bottom and discharges it from the top. It can be installed in small spaces. In the HORIZONTAL UNIT, the air flows in one side and out the other. This unit is suitable for installation in crawl spaces, attics, and basements. In another type, sometimes called a LOWBOY, both the return and the outlet are at the top. It is a shorter and wider version of the up-flow unit. The different airflows are shown in figure 4-22.

Another type of furnace is the DUCT FURNACE. It is designed for mounting in a duct system where air circulation is provided by an external fan. It is generally used with an air- conditioning system to supply heat during the heating season by using the same ductwork. This type can be installed as a single unit or in batteries for larger requirements. A

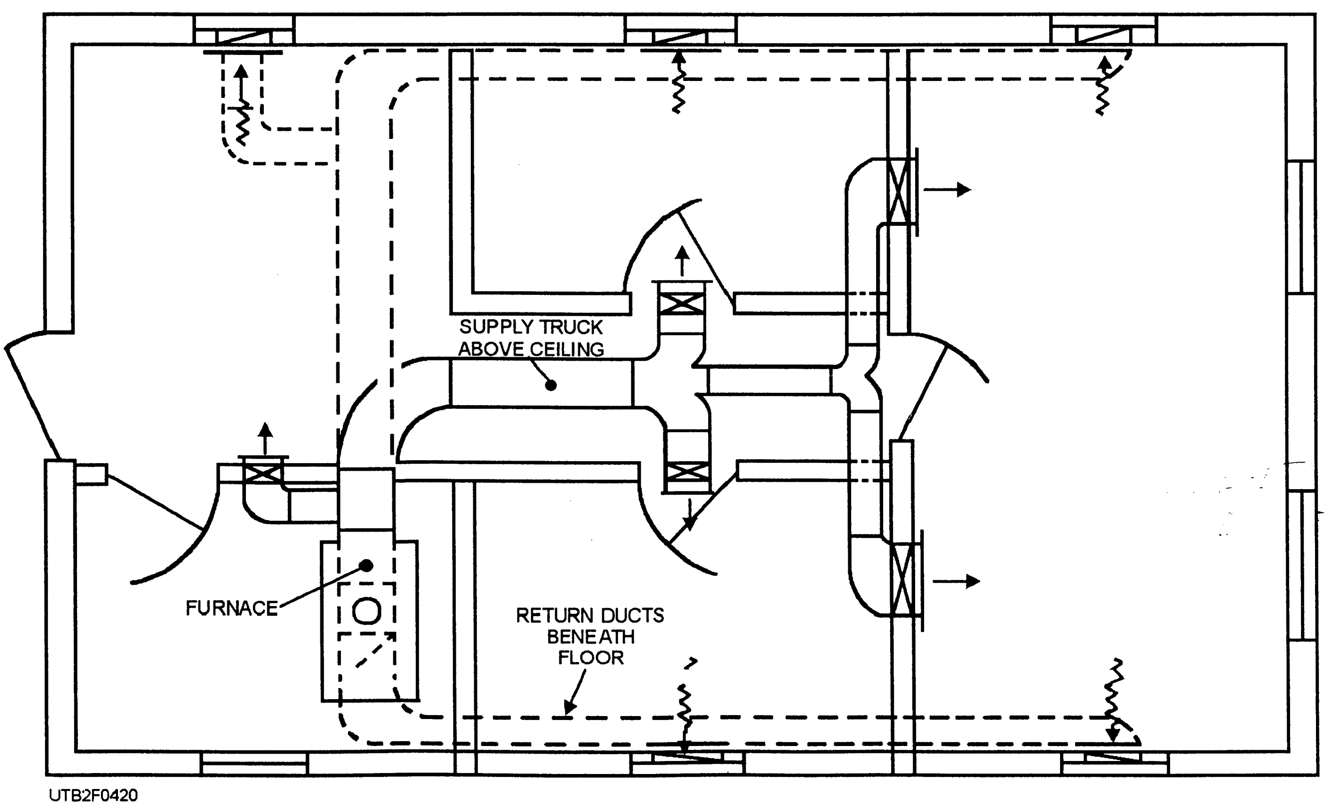

Figure 4-20.—Trunk and branch duct distribution systems.

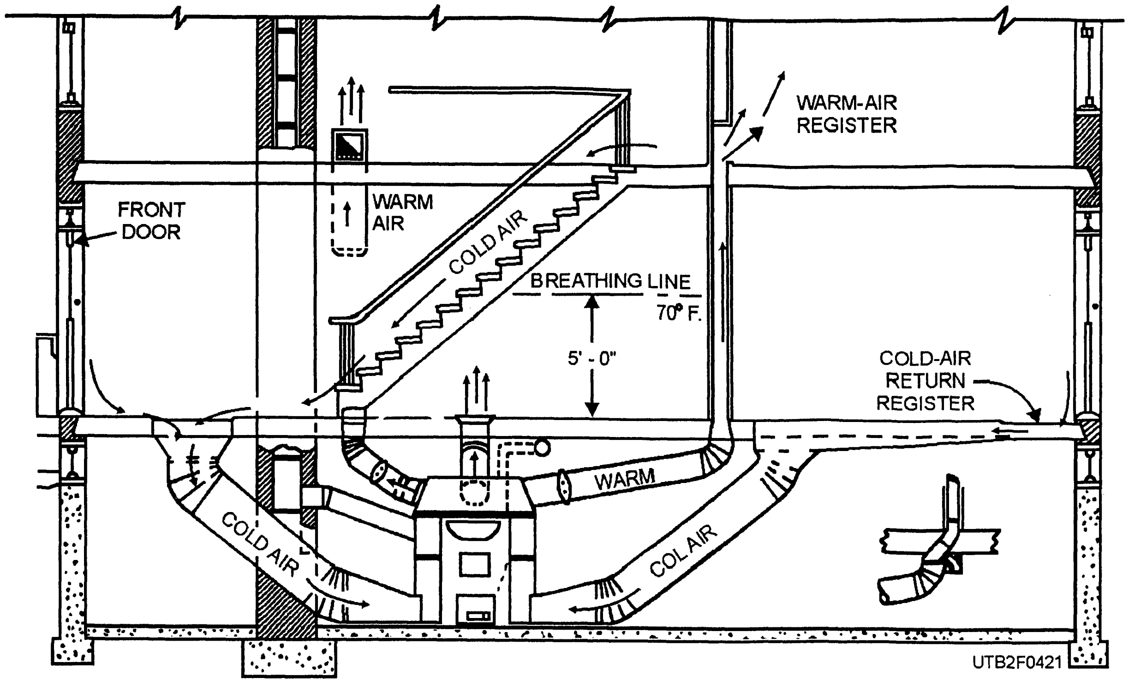

Figure 4-21.—A typical gravity warm-air heating system (individual duct).

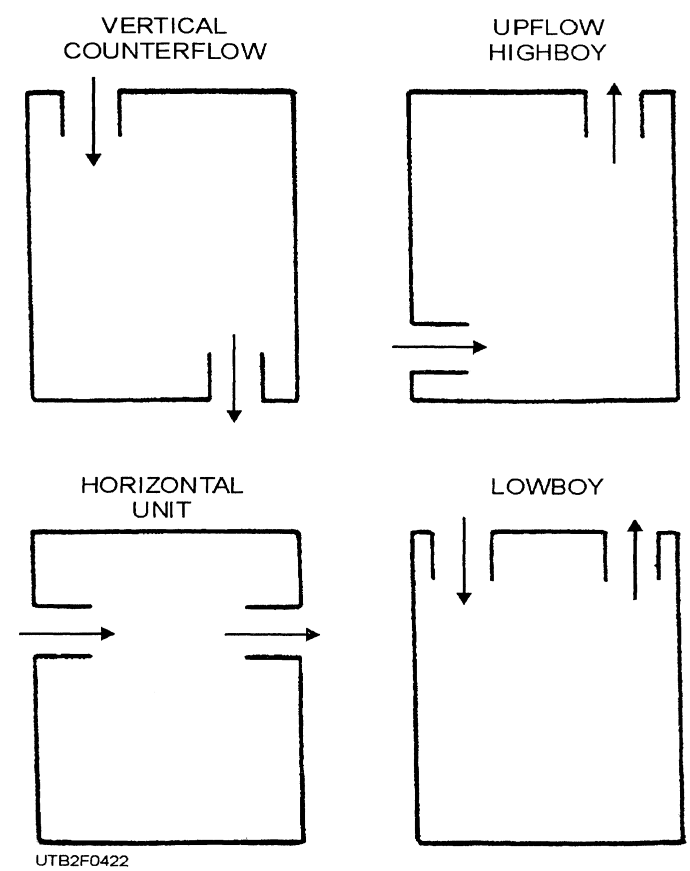

Figure 4-22.—Furnace airflow designs.

typical gas-fired duct furnace is shown in figure 4-23.

Gas-fired furnaces have three main parts—the return-air compartment that houses the blower and filter components, the warm-air compartment that includes the heat exchanger radiators and combustion enclosure, and the combustion air and fuel compartment. This arrangement is shown in figure 4-24.

Basic Components

The components and assemblies of a gas-fired furnace can be broken down into six units. Each unit is discussed briefly below. Refer to figures 4-23 and 4-24 as we go along to identify the location of individual parts.

The furnace casing, sometimes called the cabinet, along with the framework, contains and supports the components of the unit. It also provides an insulating chamber for directing return air through the heat exchanger into the warm-air outlet.

The blower is a centrifugal fan that provides the circulation required to move warm air across the heated space. It also pulls the return air from the space back to the furnace.

The burners are usually the Bunsen type regardless of their size or shape. Figures 4-25 and 4-26 show Bunsen burners. The burner nourishes the flame, as it provides the correct mixture of primary air and fuel gas to the combustion area.

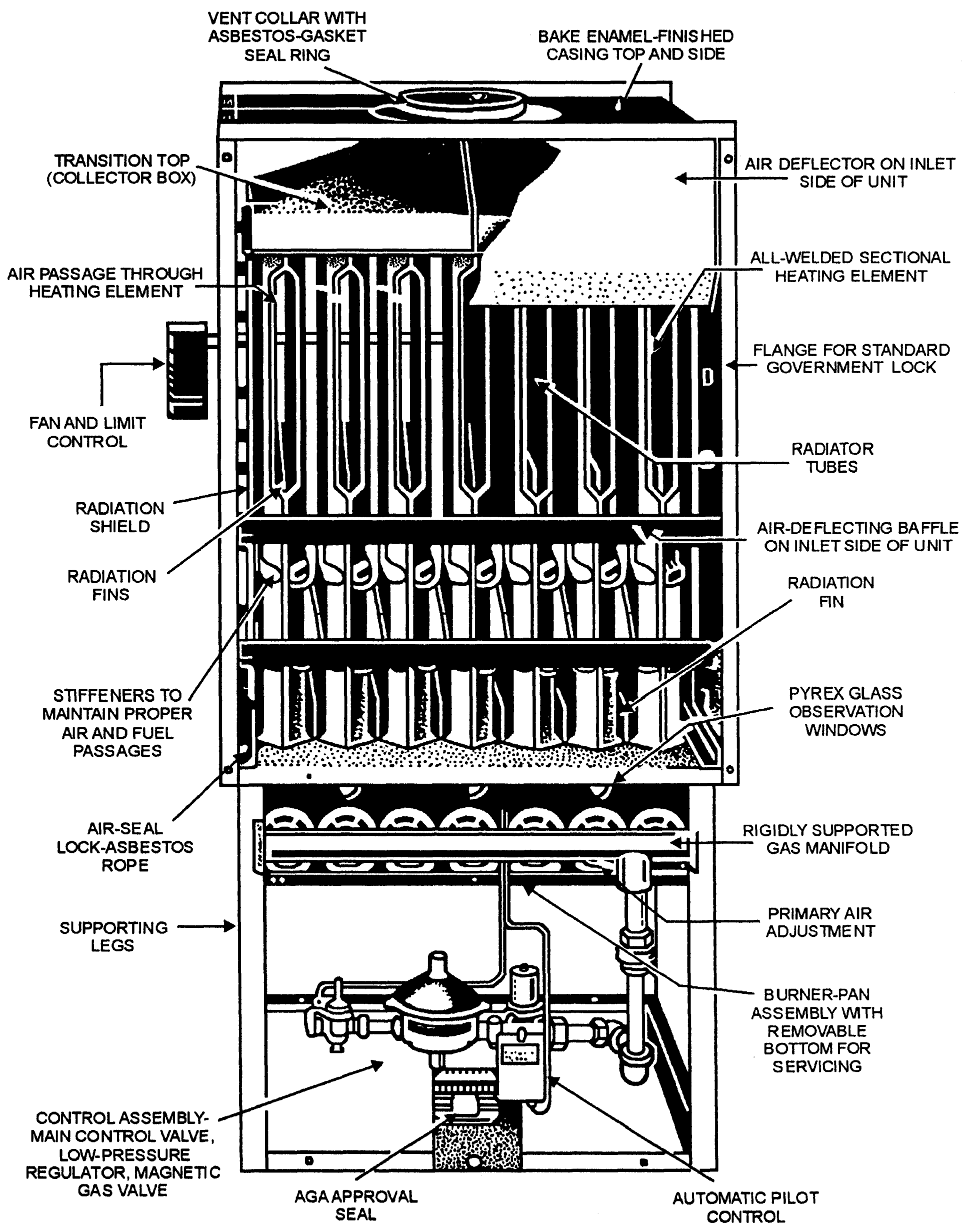

Figure 4-23.—Typical gas-fired duct furnace.

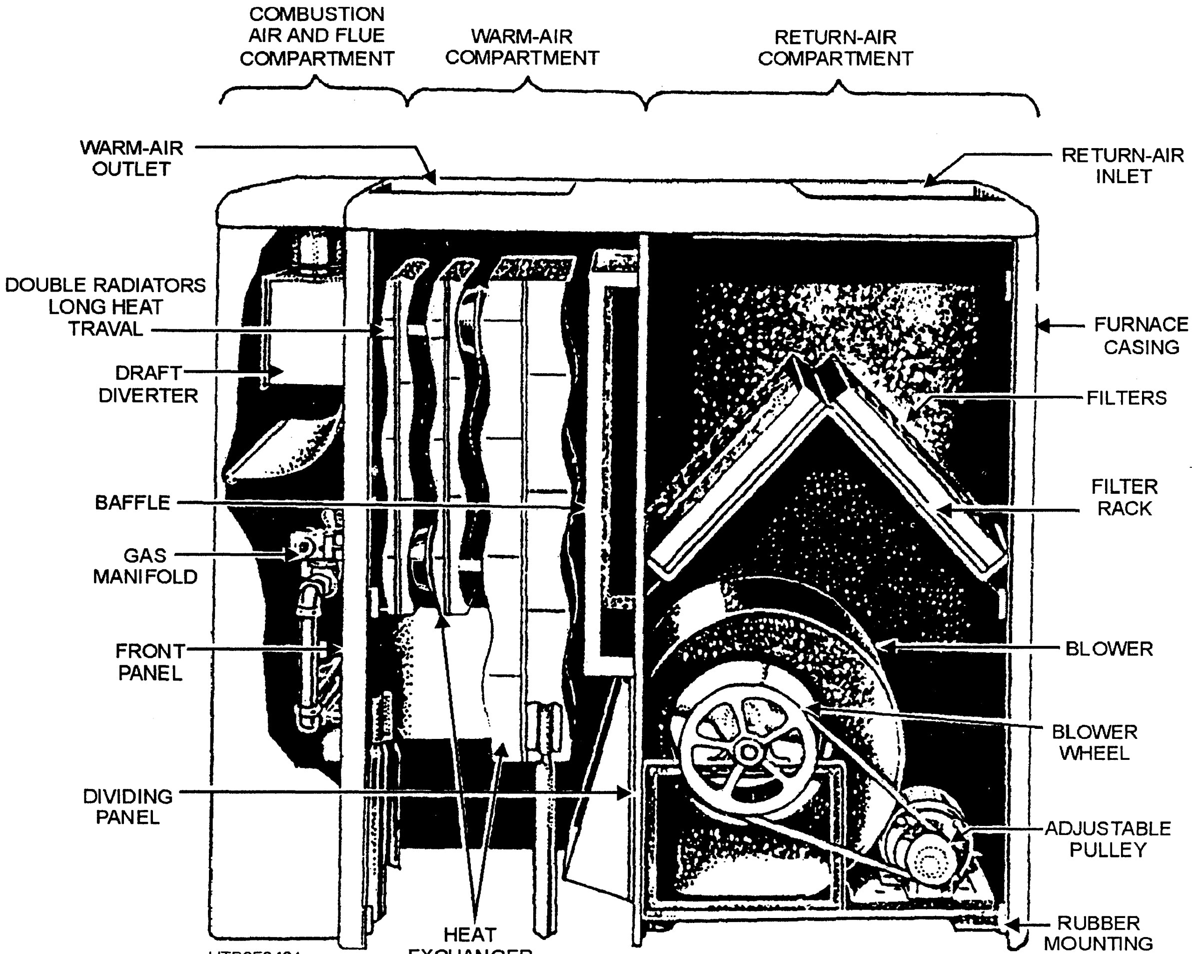

Figure 4-24.—Internal view of a furnace.

The gas manifold assembly includes the gas valves, pressure regulator, and those components that automatically control the flow of gas to the pilot and main burner. It is directly connected to the burner.

Gas Burners and Controls

To use natural gas, a nearly ideal fuel, requires comparatively simple equipment and unskilled labor. This clean gas is almost free of noncombustible and is therefore clean. However, it is relatively dangerous compared to coal or oil because it mixes easily with air and burns readily. Extreme care must be exercised to prevent or stop any leakage of gas into an unlighted furnace or into the boiler room. All gas burners should be approved by the American Gas Association and installed according to the standards of the National Board of Fire Underwriters.

The gas burners used in gas-fired furnaces usually have a nonluminous flame and are the Bunsen type, as shown in figures 4-25 and 4-26. Part of the air needed for combustion is primary air that is drawn into the burner mixing tube or "venturi," where it mixes with the gas that burns at the burner ports. The secondary air is supplied around the base of each separate burner flame by natural draft or is induced by a draft fan.

The gas burner controls include the following units—manual gas valve, gas pressure regulator, solenoid gas valve, diaphragm valve, pilot light, thermocouple, thermocouple control relay limit control, heat exchanger, draft diverter, and humidifier (fig. 4-27). A manual gas cock or valve must be installed ahead of all the controls.

MANUAL GAS VALVE.—The manual gas valve is installed on the heating unit next to the gas pressure regulator. It is used to shut off the gas to the heating unit in case some of the controls must be repaired or replaced.

GAS PRESSURE REGULATOR.—The gas pressure regulators used in domestic gas-heating systems are usually of the diaphragm type, as shown in figure 4-28. A gas pressure regulator maintains the desired pressure in the burner as long as the gas main

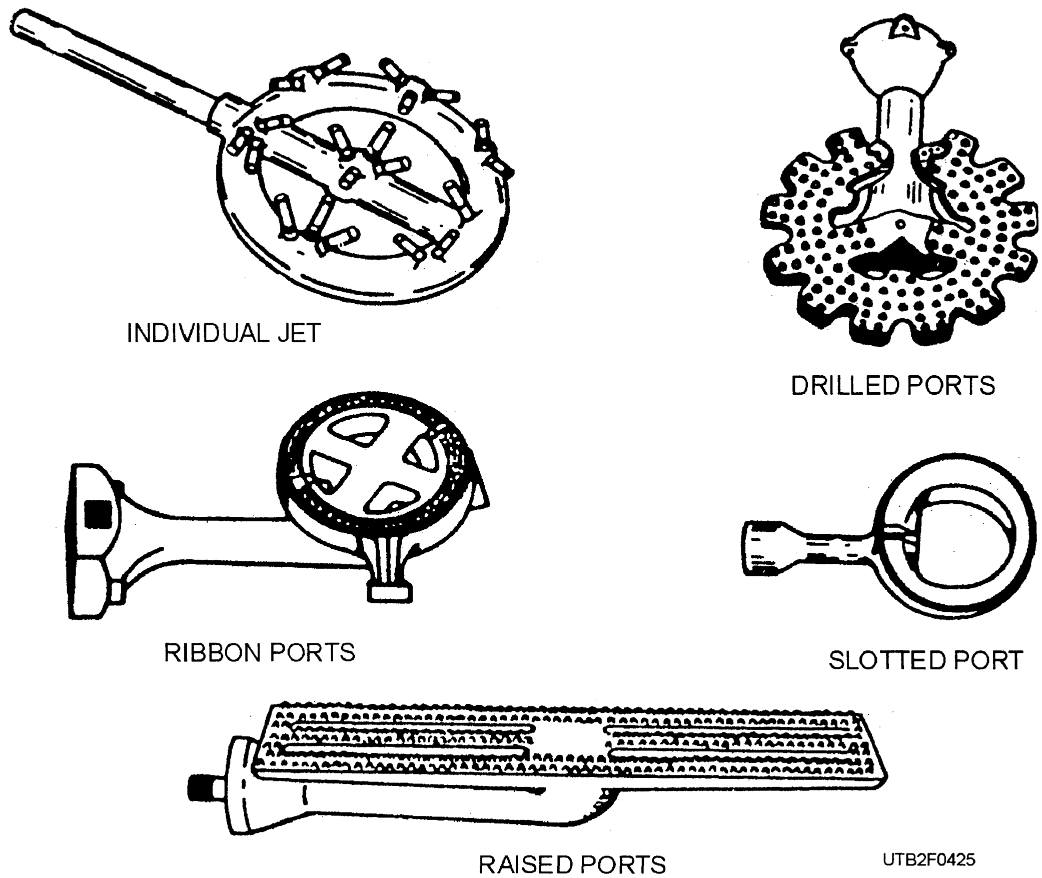

Figure 4-25.—Typical Bunsen burners.

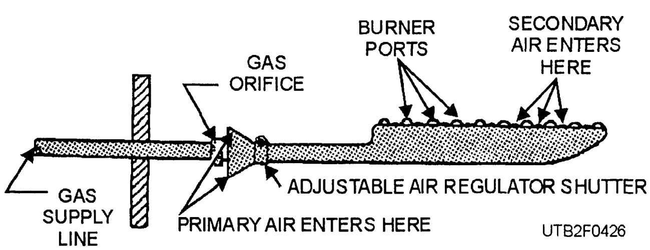

Figure 4-26.—Bunsen type of burner.

pressure is above the desired pressure. When the gas pressure to the burner is low, the pressure-regulating spring pushes the diaphragm down, in turn, pushing the pilot valve down. When the pilot valve opens, supply pressure is applied to the top of the operating piston. As the operating piston moves down, the main valve opens, admitting supply pressure to the burner. As burner pressure rises, the diaphragm is pushed up against the pressure-regulating spring, closing the pilot valve. This removes the supply pressure from the top of the operating piston and the piston return spring pushes the piston up, closing the main valve. The regulator is thus closed every time the burner pressure gets above the desired amount. Turning the adjusting screw at the top can vary the setting of the regulator.

SOLENOID GAS VALVE.—The basic principles of construction and operation applied in all solenoid gas valves are similar. However, the design of each individual unit differs somewhat from the others. The two most common types of solenoid gas valves are the standard solenoid valve and the recycling solenoid valve discussed in the following paragraphs.

The standard solenoid gas valve shown in figure 4-29 is of the electric type. It is suitable for use with gas furnaces, steam and hot-water boilers, conversion burners, and industrial furnaces. This valve operates when a thermostat, limit control, or other device closes a circuit to energize the coil. The energized coil operates a plunger, causing the valve to open. When there is a current failure, the valve automatically closes because of the force of gravity on the plunger and valve stem. The gas pressure in the line holds the valve disk upon its seat. To open this valve during current failure, use the manual-opening device at the bottom of the valve. When the electric power is resumed, you should place the manual-opening device in its former position.

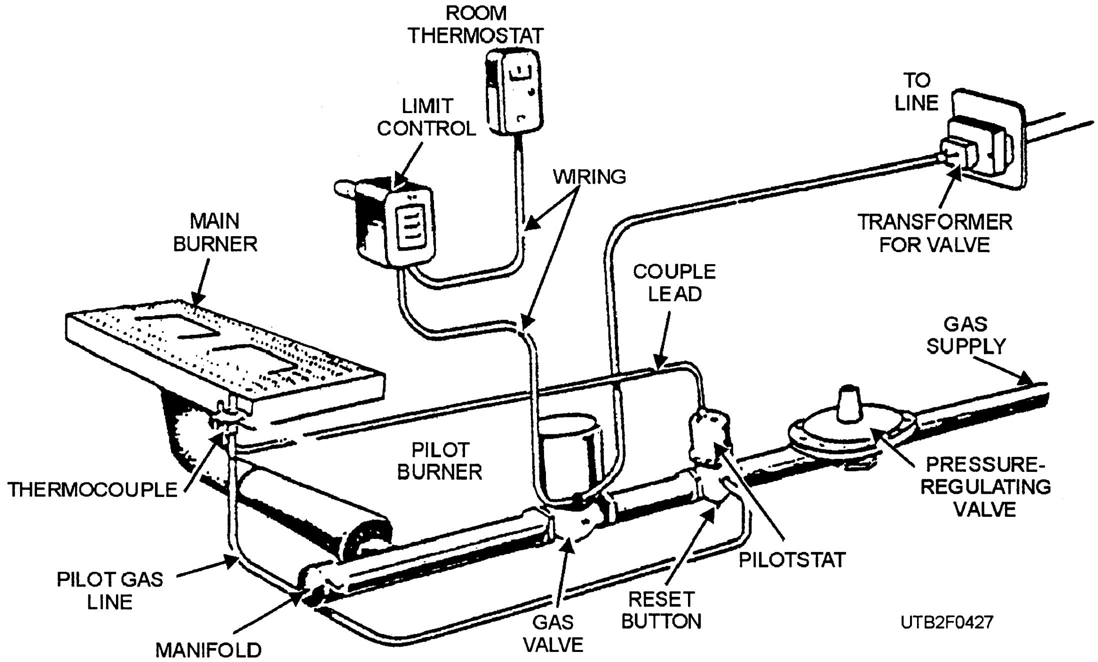

Figure 4-27.—An automatic gas burner control system.

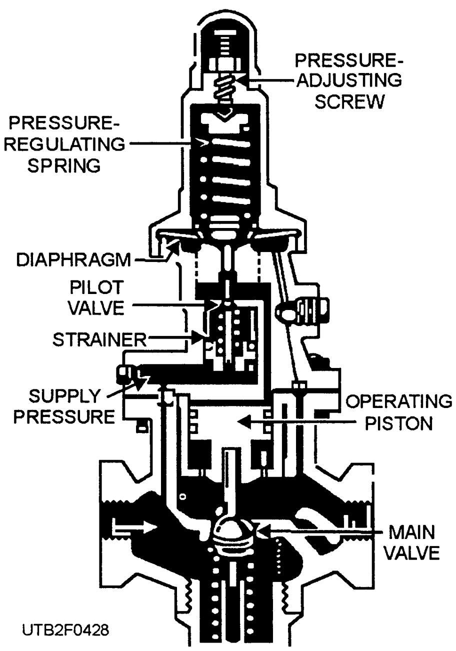

Figure 4-28.—A gas pressure regulator.

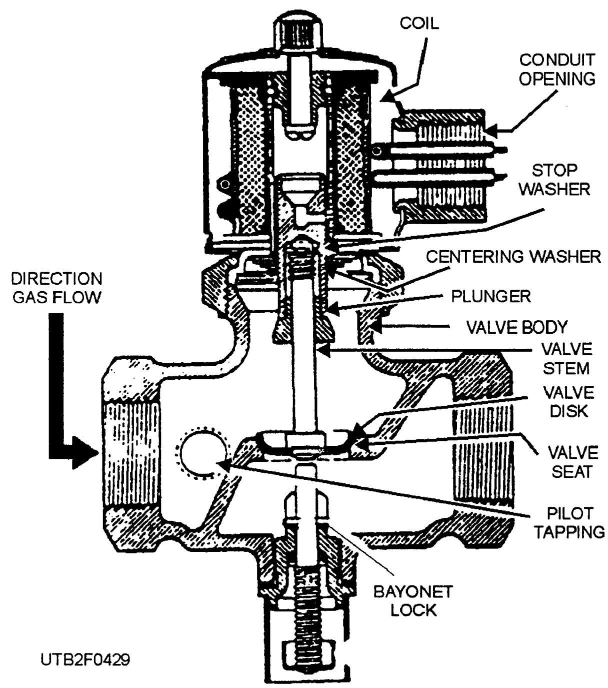

Figure 4-29.—A standard gas solenoid valve.

The recycling solenoid gas valve shown in figure 4-30 can be used with the same heating equipment as the standard solenoid gas valve. The design of this valve differs from that of the standard solenoid gas valve, because it is equipped with an automatic recycling device that allows the valve to switch to manual operation during power failure. However, upon the resumption of power, the thermostat automatically resumes control of this valve.

DIAPHRAGM VALVE.—The diaphragm gas valve shown in figure 4-31 can be used interchangeably with a solenoid gas valve. Its main feature is the absence of valve noise when it is opening or closing. In this type of diaphragm valve, the relay energizes and opens the three-way valve, so the gas pressure on the top of the diaphragm is released to the atmosphere. Reducing the pressure on the top of the diaphragm in this manner causes the gas supply pressure to flex the diaphragm upward, opening the main gas valve. When the relay is de-energized, the vent to the atmosphere is sealed and pressure from the

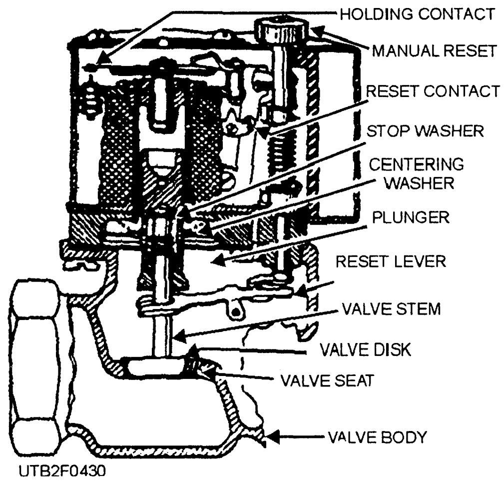

Figure 4-30.—A recycling solenoid valve.

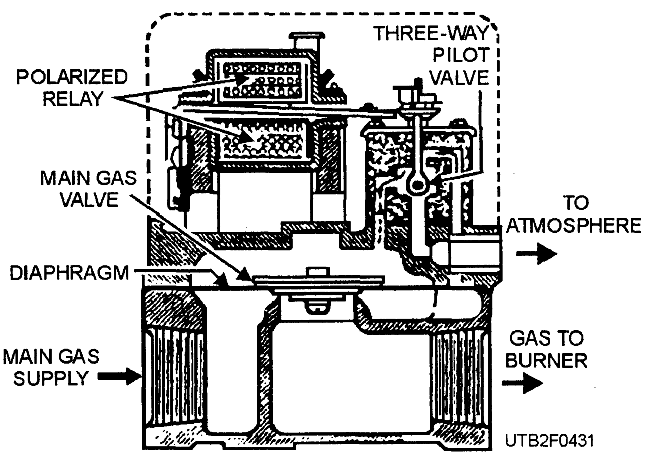

Figure 4-31.—A diaphragm gas valve.

gas supply is allowed to be applied to the top of the diaphragm, forcing it down and sealing the main valve.

PILOT LIGHT.—The gas pilot light in a gas-heating unit is a small flame that burns continuously and lights the main burner during normal operation of the heating unit. It is located near the main burner, as shown in figure 4-27.

The gas flow to the pilot light is, in some cases, supplied by a small, manually operated gas shutoff valve on the main gas line above the main gas valve. In other cases, the gas can be supplied from the pilot tapping on a solenoid gas valve, as shown in figure 4-29. In more expensive heating units, the gas for the pilot light is often supplied by a thermocouple-controlled relay.

THERMOCOUPLE.—A thermocouple is probably the simplest unit in the electrical field that is used to produce an electric current by means of heat. It is constructed of two U-shaped conductors of unlike metals in the form of a circuit, as shown in figure 4-32. If these conductors were composed of copper and nickel, respectively, and are joined as shown in the figure, two junctions between the metals exist. If a flame heated one of these junctions, a weak electric current would be produced in the circuit of these conductors. A series of junctions can be arranged to form a thermopile to increase the amount of current produced, as shown in figure 4-33.

In the heating field, thermocouples and thermopiles are used to produce the electrical current used to operate such units as gas valves, relays, and other safety devices.

The thermocouple is located next to the pilot light of the main gas burner, as shown in figure 4-27. It generates the electric current (usually 50,000 microvolts) which holds open a main gas valve, a relay, or any other safety devices, permitting gas to flow to the main burner. Soon after the pilot light is extinguished, current ceases to flow to these safety devices, thus causing them to shut off the gas to the heating unit. These safety devices will not operate again until the pilot light is lighted and current is again generated by the thermocouple.

THERMOCOUPLE CONTROL RELAY.—The thermocouple-operated relay shown in figure 4-34 is a safety device used on gas-fired heating equipment. The thermocouple, when placed in the gas pilot flame, generates electricity. The electric current energizes an electromagnet that holds a switch or valve in the OPEN position as long as the pilot flame is burning. When the pilot flame goes out because of high drafts or fuel failure, the electromagnet is de-energized, thus closing and preventing the opening of the switch or valve. The

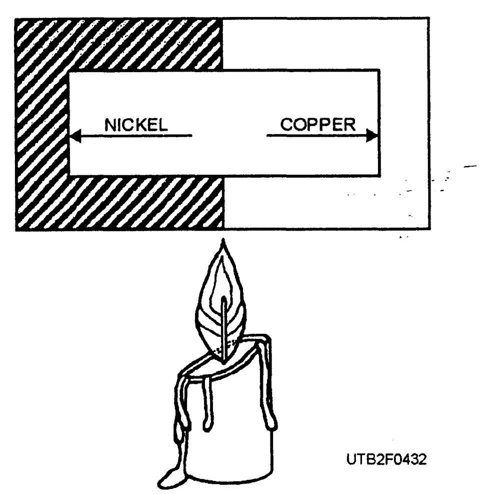

Figure 4-32.—The principle of a thermocouple.

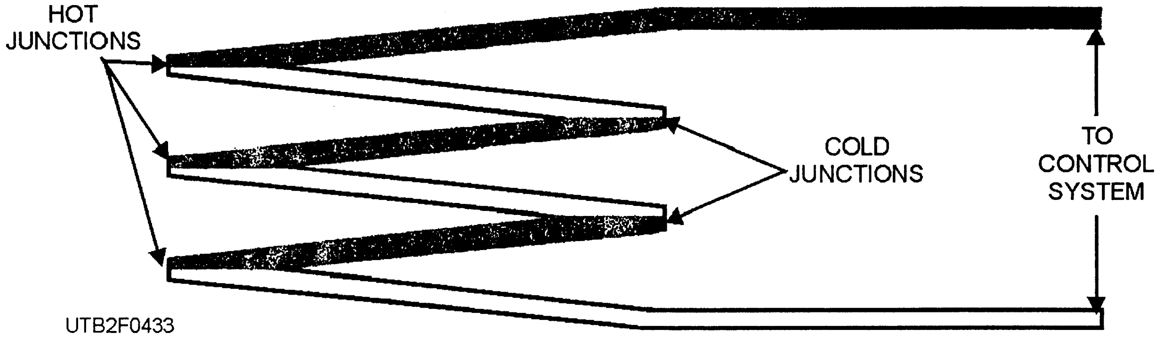

Figure 4-33.—A thermopile.

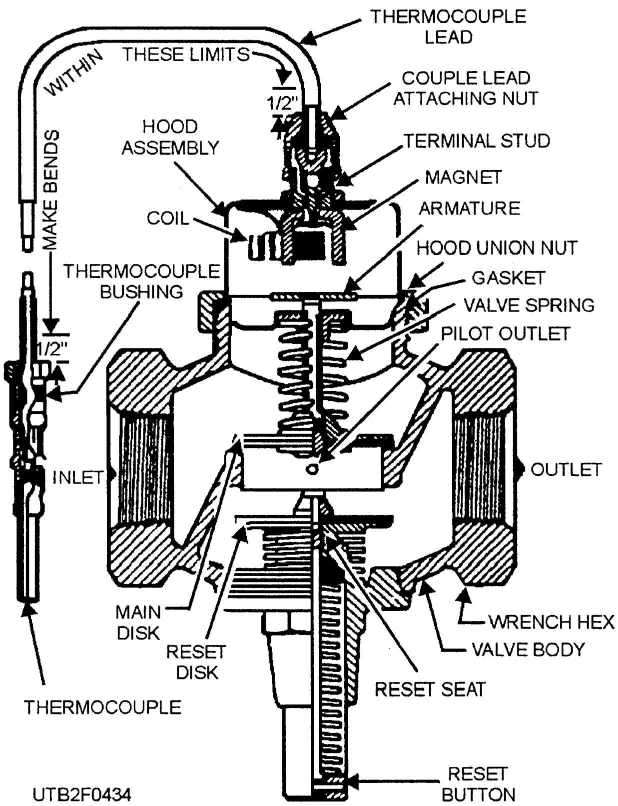

Figure 4-34.—A typical thermocouple and valve relay assembly.

closing of the valve or switch prevents the burner from filling the combustion chamber with unburned gases.

To re-light the pilot light, push up the reset button at the bottom of the relay and allow the gas to flow to the pilot light. Since some heating units are not equipped with relays, the pilot light is not automatically shut off in case of gas supply failure.

The relay shown in figure 4-35 is an electrical switch type of relay. It is entirely electrical and can be used as a controlling unit for either the magnetic or diaphragm gas valves. This unit is actuated by the electric current generated by the thermocouple. It controls the operation of the gas valve in the magnetic and diaphragm valves. A relay of this type must also be reset manually for normal operation.

LIMIT CONTROL.—The limit control in a gas burner system is a safety device. It shuts off the gas supply when the temperature inside the heating unit becomes excessive. The limit control device can be adjusted to the desired setting. It exercises direct control on the gas or diaphragm valve.

HEAT EXCHANGER.—This unit or assembly may be either a single or sectional contoured steel shell. It extends vertically from the burner enclosure to the flue exit. Functionally, it transmits heat from the hot gases of combustion to the circulating warm air that passes the outer surfaces.

Draft Diverter.—The diverter is simply a sheet metal chamber that encircles the flue. It has an opening at the bottom to allow air to be drawn in by the flue draft. Its purpose is to reduce the downdrafts and updrafts that are objectionable to pilot and burner operation.

Humidifiers. —Humidifiers used with forced warm-air heating systems are usually of the pan type shown in figure 4-36. Unless the water is relatively free of solids, these humidifiers require frequent attention, since the float may stick in the OPEN position or the valve may clog. Overflowing of the pan may result in a cracked heating section, and a stopped-up inlet valve will make the humidifier inoperative.

The drum type of evaporative humidifier uses an evaporation pad in the shape of a wheel. The slow-turning wheel is submerged in the water in the lower pan where the spongelike plastic foam material becomes saturated with water. The wheel lifts this portion of the pad and exposes it to the warm, dry air flowing through it. The air then absorbs more moisture because of lower relative humidity at a higher temperature.

OIL-FIRED FURNACES

Oil-fired furnaces are similar to gas-fired units in physical arrangement. Internally, oil-fired units have three areas—the burner compartment, the combustion

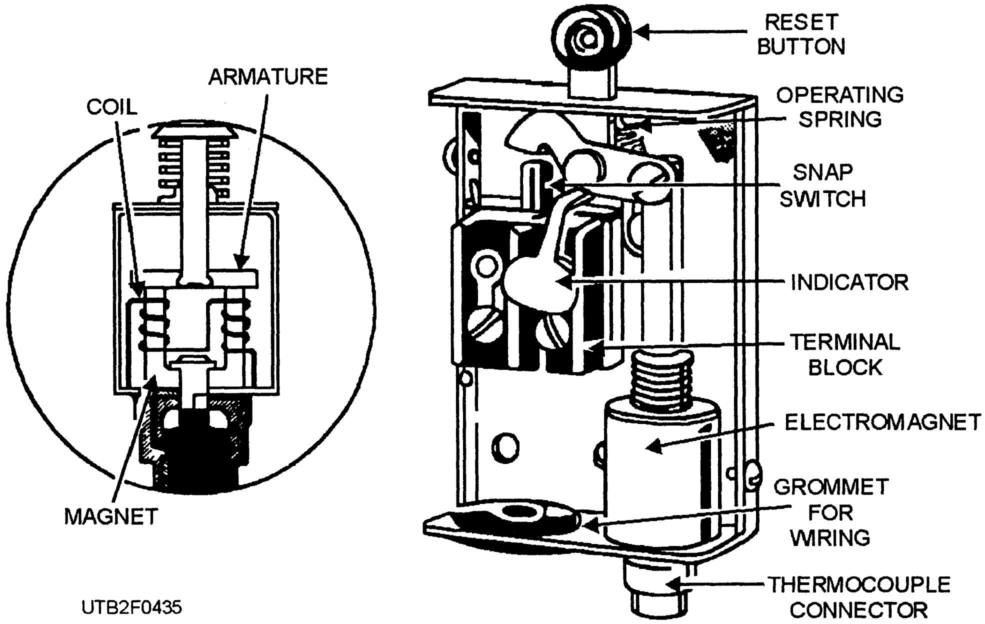

Figure 4-35.—An electric switch type of relay.

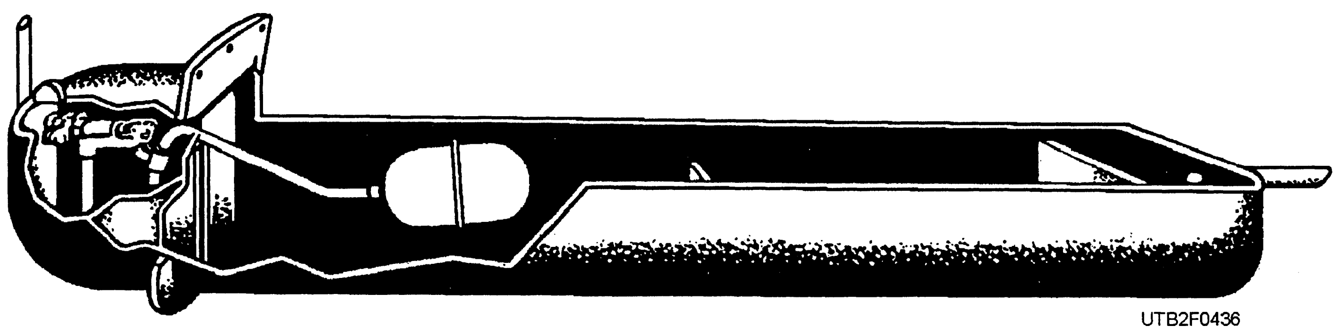

Figure 4-36.—Cutaway view of a typical humidifier.

and radiating chamber, and the blower compartment. Figure 4-37 shows a cutaway view of a typical oil-fired furnace.

Like gas-fired units, oil-fired units are also available with various airflow designs. The model shown in figure 4-15 is designed with both the return-air inlet and the warm-air outlet in the top. More compact models (fig. 4-37) are available with the return-air inlet at the side or bottom below the radiating and combustion area. The warm-air outlet is at the top.

A floor furnace is shown in figure 4-38. This type of oil-fired unit is smaller, lighter in construction, and is designed to be hung from the floor of the space served. Only a minimum of clearance is required below the floor.

Oil burners may be separated into various classes, such as domestic and industrial. Since domestic oil burners are used almost universally in warm-air furnaces, they are the only ones covered in detail in this chapter.

Domestic Oil Burners

Domestic oil burners atomize the oil and are usually electrically power driven and are used in small central heating plants. They deliver a predetermined quantity of oil and air to the combustion chamber, ignite it, and automatically maintain the desired temperature.

Domestic oil burners are classified according to various methods, none of which is entirely satisfactory because of the overlapping among a great number of models. Classification may be by type of ignition, draft, operation, method of oil preparation, or features of design and construction.

DESIGN AND CONSTRUCTION.—One of the most common types of domestic oil burners is the pressure-atomizing gun type of burner. Gun type

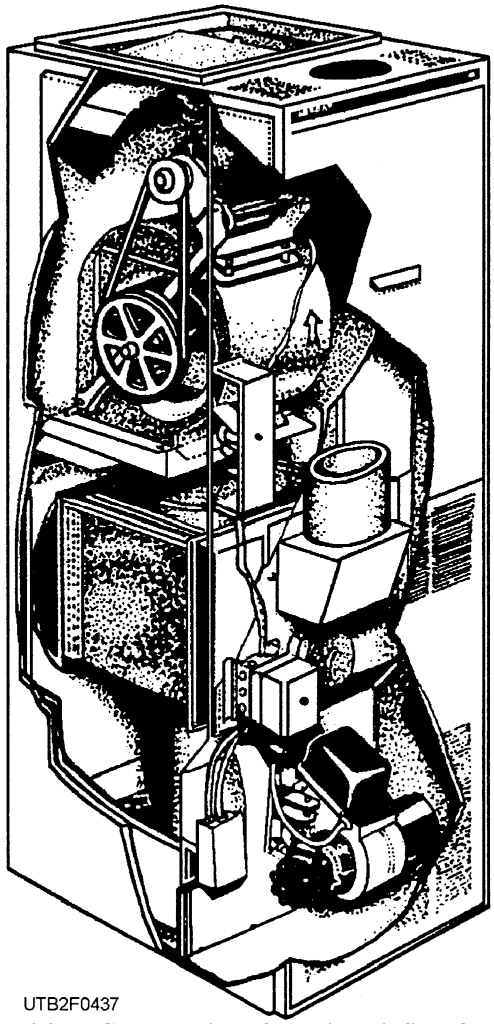

Figure 4-37.—Cutaway view of a typical oil-fired furnace.

burners atomize the oil by fuel-oil pressure. The fuel-oil system of a pressure-atomizing burner consists of a strainer, pump, pressure-regulating valve, shutoff valve, and atomizing nozzle (fig. 4-39). The nozzle and electrode assembly includes the oil pipe, nozzle holder, nozzle, strainer, electrode insulators, electrodes, supporting clamp for all parts, and static disk. The oil pipe is a steel rod with a fine hole drilled through it. This hole reduces oil storage in the nozzle to a minimum that prevents squirting at the nozzle when the burner shuts off.

The air system consists of a power-driven blower with means to throttle the air inlet, an air tube that surrounds the nozzle and electrode assembly, and vanes or other means to provide turbulence for proper mixing of the air and oil. The blower and oil pump are generally connected by a flexible coupling to the burner motor. Atomizing nozzles can be furnished to suit both the angle of spray and the oil rate of a particular installation. Flame shape can also be varied by changing the design of the air exit at the end of the air tubes. Oil pressures are usually about 100 psi, but pressures considerably greater are sometimes used.

Electric ignition is almost exclusively used. Electrodes are located near the nozzle but must not be in the path of the fuel oil spray. The step-up transformer provides the high voltage (usually 10,000 volts) necessary to make an intense spark jump across the electrode tips.

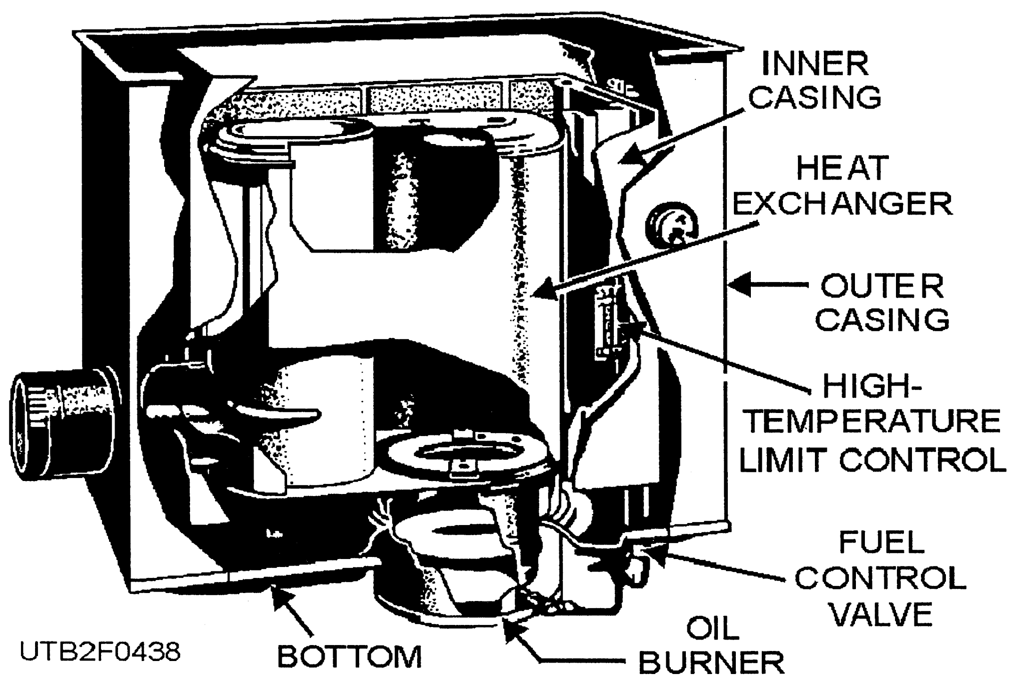

Figure 4-38.—Oil-fired floor furnace.

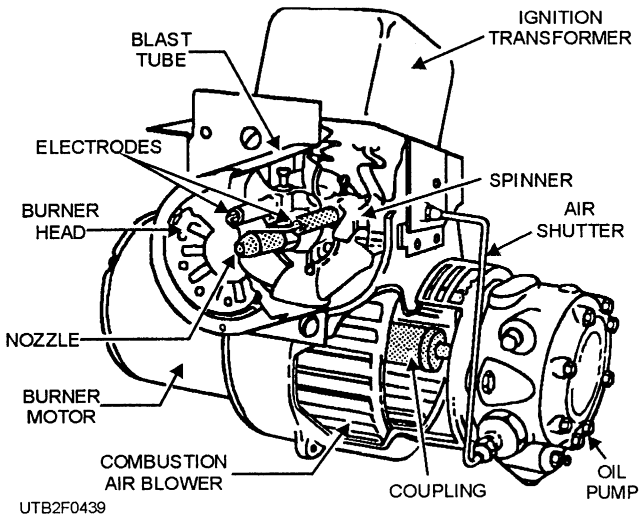

Figure 4-39.—High-pressure gun type of oil burner.

FUEL UNIT.—There are many types of fuel units available for oil burners; however, the T-type, two-stage fuel unit is the most commonly used. Figure 4-40 shows this type of unit. It is an oil pump with two strainers mounted on the body of the oil burner and operated by the blower motor shaft.

The T-type, two-stage fuel unit can be used on a single-line or on a two-line system. When Number 1 on the strainer cover is next to the letter marked on the body of the pump, it is correctly arranged for a single-line system. It is set up for a two-line system when the cover is turned so Number 2 is adjacent to the same letter.

A two-line system is necessary when the bottom of the fuel tank is below the level of the pump. The suction line from the tank is connected to the pump port marked "Inlet." The return line is connected to the pump bypass port and is directed back into the tank. With the one-line system, the return line is not used.

Ignition Electrodes.—The heat of a spark jumping between two ignition electrodes ignites the fuel (fig. 4-39). The voltage necessary to cause the spark to jump is much more than the line voltage available. Therefore, an electric transformer is used to step up the line voltage to approximately 10,000 volts.

The wall flame burner has an oil distributor and fan blades mounted on a vertical shaft directly connected to the motor. The oil distributor projects the oil to a flame ring made of either refractory material or metal. Figure 4-41 shows this type of burner. The hot flame ring vaporizes the oil, and the oil vapors mix with air and burn with a quiet blue flame that sweeps the walls of the furnace. Ignition may be electric, gas-electric, or gas. High-grade fuel oil is necessary for satisfactory performance.

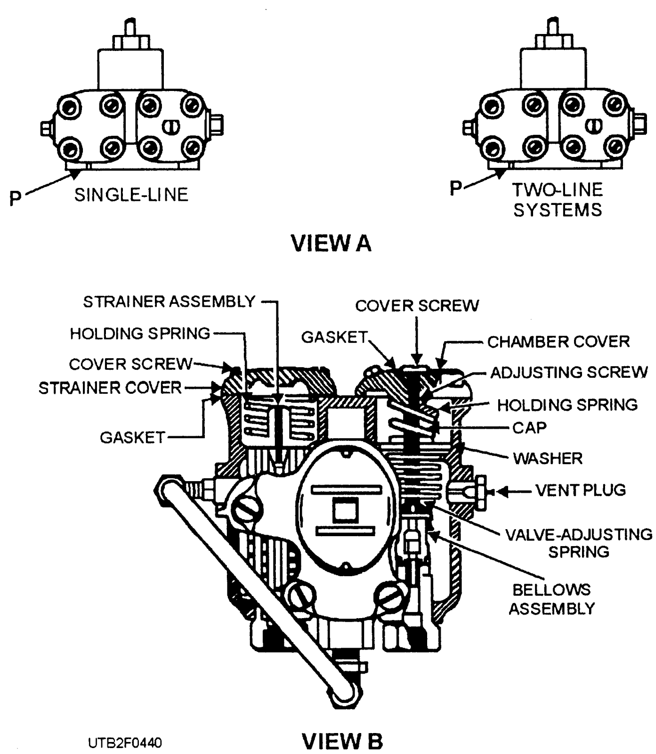

Figure 4-40.—A typical T-type, two-stage fuel pump.

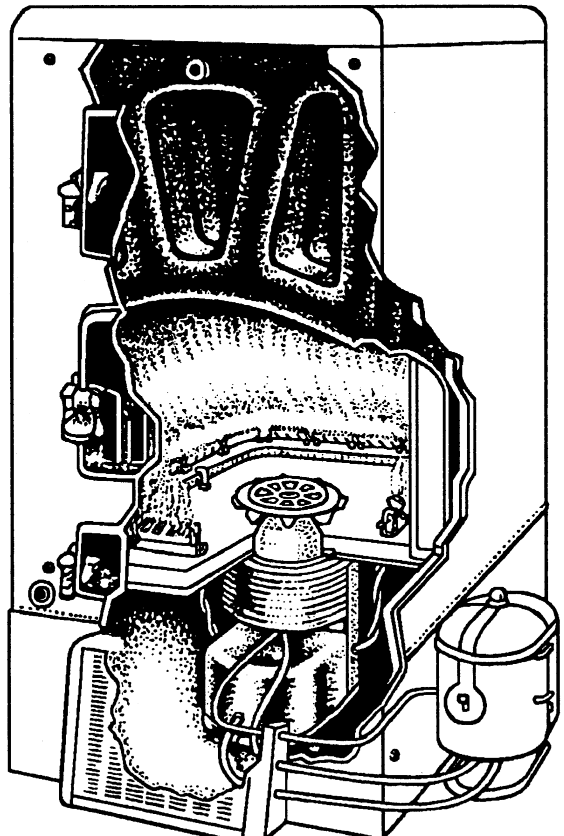

Figure 4-41.—Vertical-rotary burner of the vaporizing or wall flame type.

Horizontal Rotary Type.—The horizontal rotary type was originally designed for industrial use; however, sizes are available for domestic use. It has a wider range of fuel-burning capacity than the high-pressure gun type and can accommodate heavier grades of fuel. Figure 4-42 shows this type of burner.

The major parts of the burner are the housing, fan, motor, fuel tube, and rotating atomizing cup. The atomizing cup and fan are driven at the same speed by a directly connected electric motor. Oil is fed through the fuel tube to the inner surface of the atomizing cup. The oil spreads over the surface of the cup, which turns at 3,450 revolutions per minute (rpm). It then flows to the edge of the cup where it is thrown off. The whirling motion and the resulting centrifugal force separates the oil into fine particles, as it leaves the cup. Primary air supplied by the fan is thrown in around the outer edge of the rotating cup and given a whirling motion in the direction opposite that of the oil. The streams of air and oil collide and thoroughly mix, as they enter the combustion chamber.

OIL BURNER CONTROLS.—The purpose of oil-burner controls is to provide automatic, safe, and convenient operation of the oil burner. The system is designed to maintain the desired room temperature, to

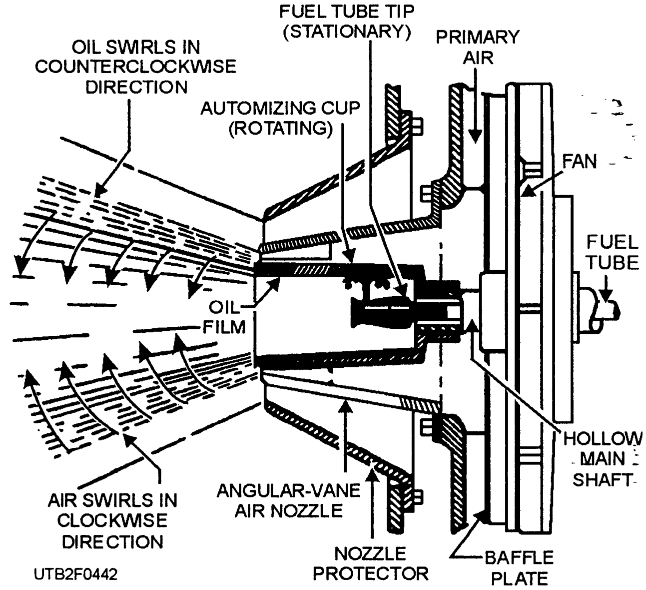

Figure 4-42.—A horizontal-rotary oil burner.

start the burner as required, and to ignite the fuel to initiate combustion. However, in case trouble arises during operation, the burner must be stopped and further operation prevented until the trouble has been corrected.

Oil-burner controls are essentially the same as stoker or gas controls. The only difference is that the oil burner has, in addition, two ignition electrodes and a primary or safety control. A diagram of a typical forced warm-air control system is shown in figure 4-43.

Primary Control.—The burner primary control is electrically connected between the thermostat and the burner, as shown in figure 4-43, and it performs several functions. The primary control closes the motor and ignition circuits when the thermostat calls for more heat. It breaks the motor circuit and stops the burner when the motor first starts if the fuel fails to ignite or if the flame goes out. The control prevents starting of the burner in case of electrical failure until all safety devices are in the normal starting position.

An interior view of a primary control is shown in figure 4-44. This control device is also equipped with a high-temperature limit control. This control shuts down the heating plant whenever the temperature of the furnace becomes excessive. For example, if the thermostat is exposed to a blast of cold air for a long period of time, the heating plant could run long enough to become overheated to the point of severe damage or external fire if it was not for this high-temperature limit control.

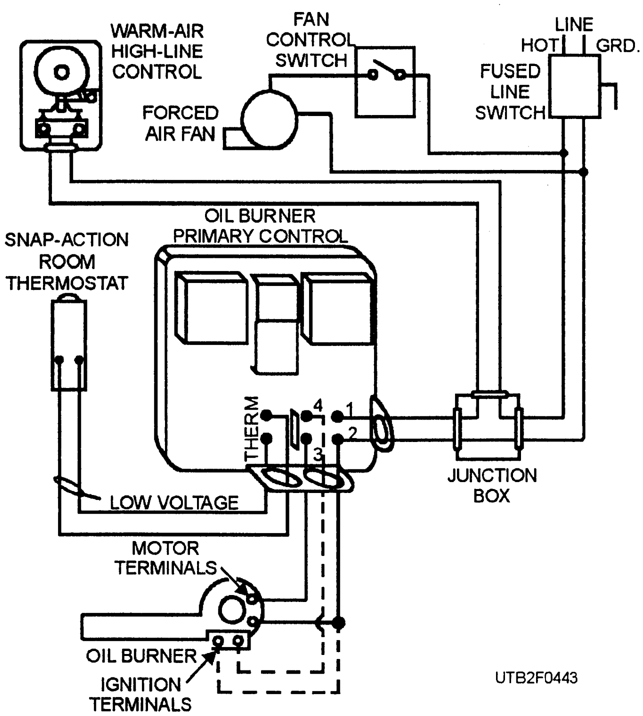

Figure 4-43.—Typical forced warm-air control system.

Limit Control.—The limit control is a device that responds to changes in air temperature (in a warm-air heating system), to changes in water temperature (in a hot-water heating system), and to changes in steam pressure (in a steam-heating system). The limit control has two distinct functions. The first function is to control the operation of the fire so the temperature and pressure of the heating plant never exceeds safe operating limits. This function is distinctly for safety control.

The second function of the limit control is to limit the temperature and pressure of the heating system for better temperature regulation in the building. This function is particularly useful in controlling coal-fired heating systems where the coal bed continues to give off heat when the stoker motor stops. By lowering the setting of the limit control, however, it is possible to prevent an excessively hot fire that would continue to throw off excessive amounts of heat after the thermostat has been satisfied.

Temperature-Responsive Devices.—Many automatic control units, such as the thermostat, limit control, fan control, and many others, must respond to temperature changes. Actually, these are the instruments that use a temperature change to cause the electrical contacts inside each unit to open and close. The opening and closing is an indicating signal that is transmitted to the primary control for specific action, such as starting or stopping the operation of the heating plant.

Bimetallic Strip.—Some automatic control units are equipped with a switch that contains a straight

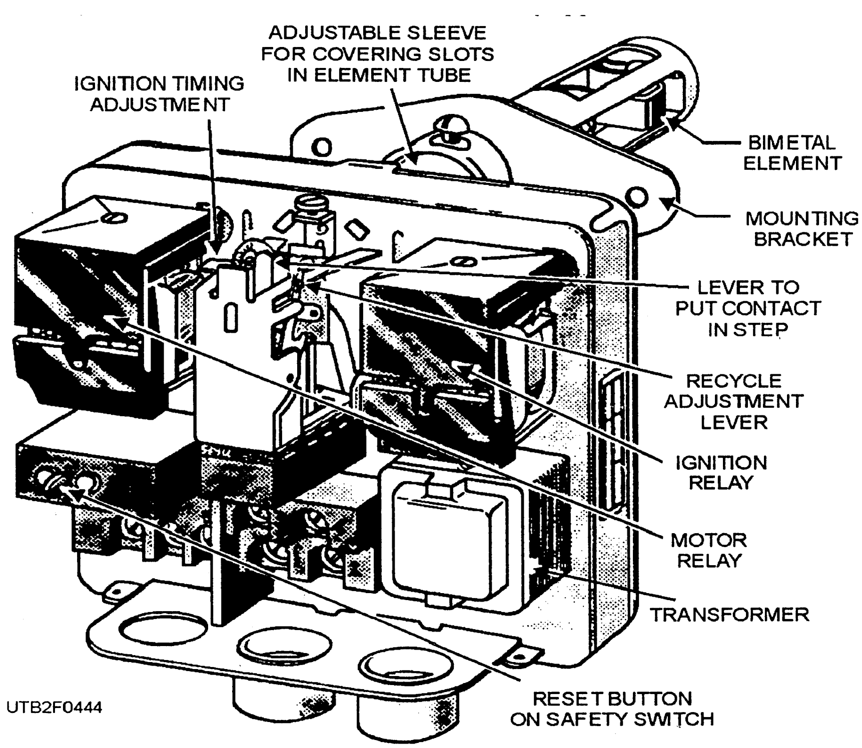

Figure 4-44.—Interior view of a primary control.

bimetallic strip to open and close electrical contacts. This actuating device is made by welding together two pieces of dissimilar metals, such as brass and Invar, as shown in figure 4-45, view A. Below a certain predetermined temperature, this strip does not deflect or bend. However, when the strip is heated, it bends in the direction of the metal that expands the least, as shown in figure 4-45, view B.

Actually, this electrical switch is constructed, as shown in figure 4-45, view C, by welding two electrical connections and contacts to the strip. A switch of this type can then be used to control electrical circuits, because the bimetallic strip responds to temperature changes. This is a basic example of how this principle of bimetallic strip operation is used in many temperature-responsive automatic units. Other control switches contain bimetallic strips that are spiral, U-shaped, Q-shaped, or even in the shape of a helix, as shown in figure 4-46.

Vapor-Tension Device.—The vapor-tension principle is also used to actuate some types of automatic control units. This is a common type of temperature-measuring device in which the effects of temperature changes are transmitted into motion by a highly volatile liquid. The most used vapor-tension device is the simple compressible bellows, as shown in figure 4-47, view A.

The bellows is made of brass. It is partially-filled with alcohol, ether, or other volatile liquid not

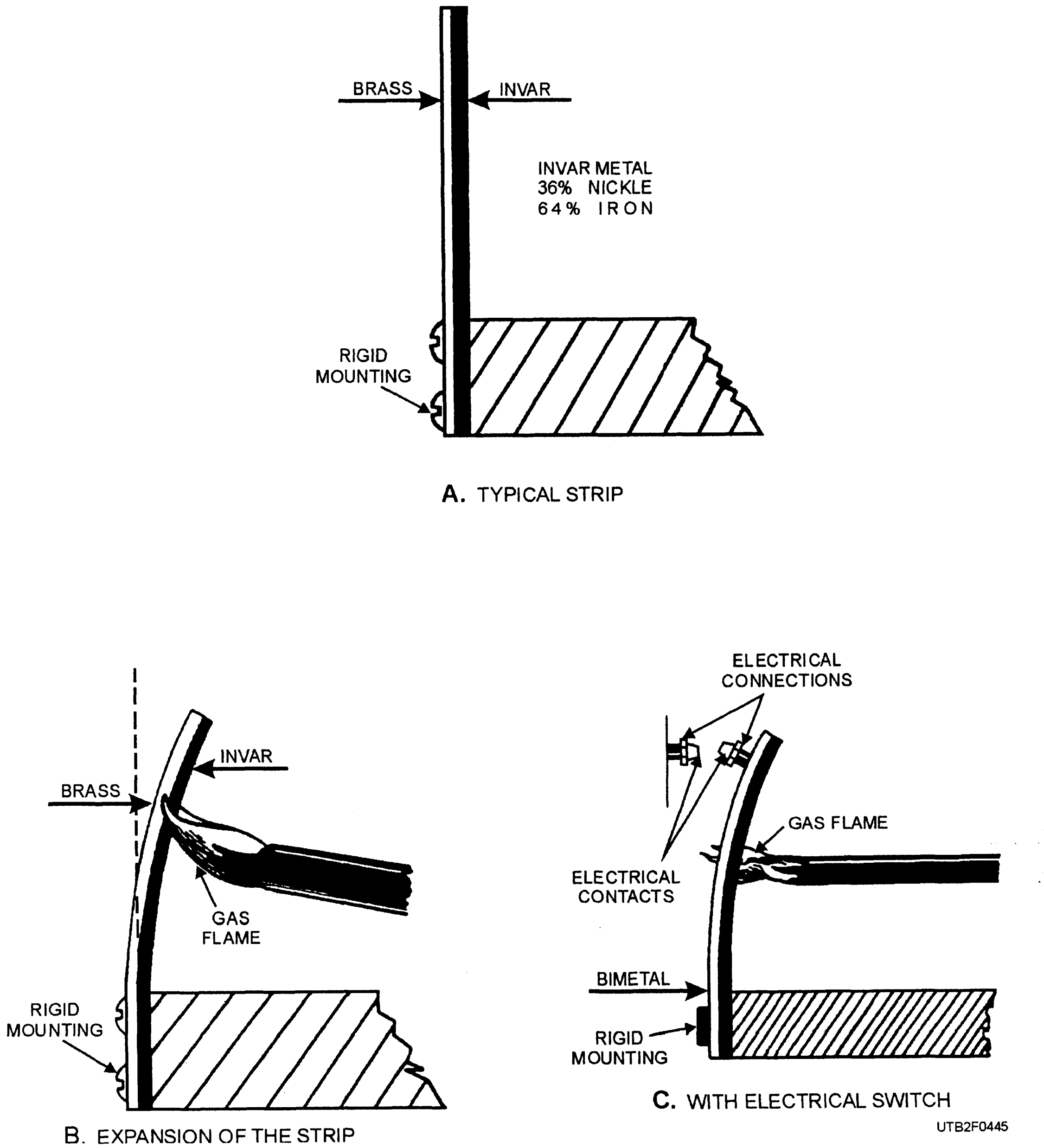

Figure 4-45.—Bimetallic strips: A. Typical strip; B. Expansion of the strip; C. With electrical switch.

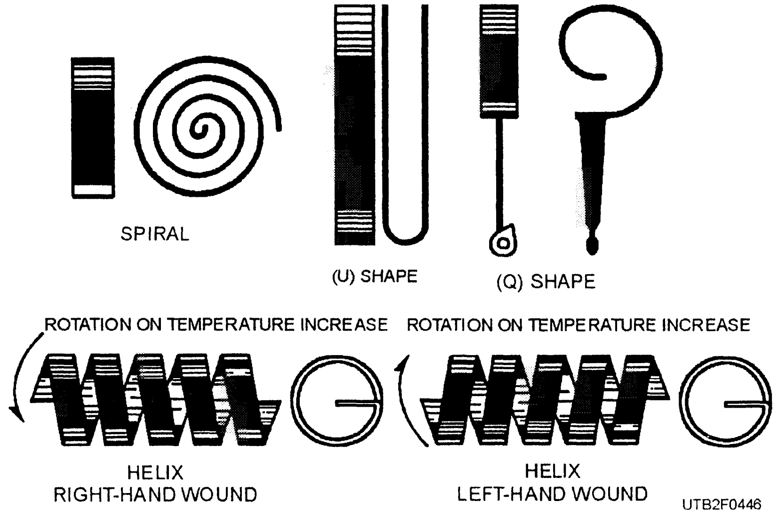

Figure 4-46.—Various types of bimetallic strips.

corrosive to brass. When the temperature around the bellows increases, the heat gasifies the liquid inside and causes the bellows to extend. The extension closes a set of electrical contacts, as shown in figure 4-47, view B. When the bellows cools again, it contracts. The contraction opens the electrical contacts.

Remote-Bulb Device.—Liquid-filled devices are not always limited to the simple bellows. There are some remote-bulb devices that not only have a bellows but also have a capillary tube and a liquid-filled bulb, as shown in figure 4-48.

When the liquid in the bulb is heated, part of it gasifies and forces its way through the capillary tube into the bellows. This increased pressure inside the bellows causes it to extend and open a set of electrical contacts (or open or close a valve). When the bulb cools, the gas liquefies and decreases pressure inside the bell ows. This decreased pressure allows the bellows to contract and close the electrical contacts.

Pressure-responsive devices are actuating mechanisms installed in units, such as steam-pressure controls, steam-pressure gauges, and pressure regulators.

Bellows.—One type of pressure-responsive actuating device uses bellows in a way similar to that of the remote-bulb type. In this application, the bellows extends and contracts in response to changes in steam pressure. The action caused by movement of the bellows opens or closes a set of electrical contacts.

Bourdon Tube.—Another type of pres sure-responsive actuating device is found inside of the pressure gauge shown in figure 4-49. In this actuating device, the pressure is applied inside a

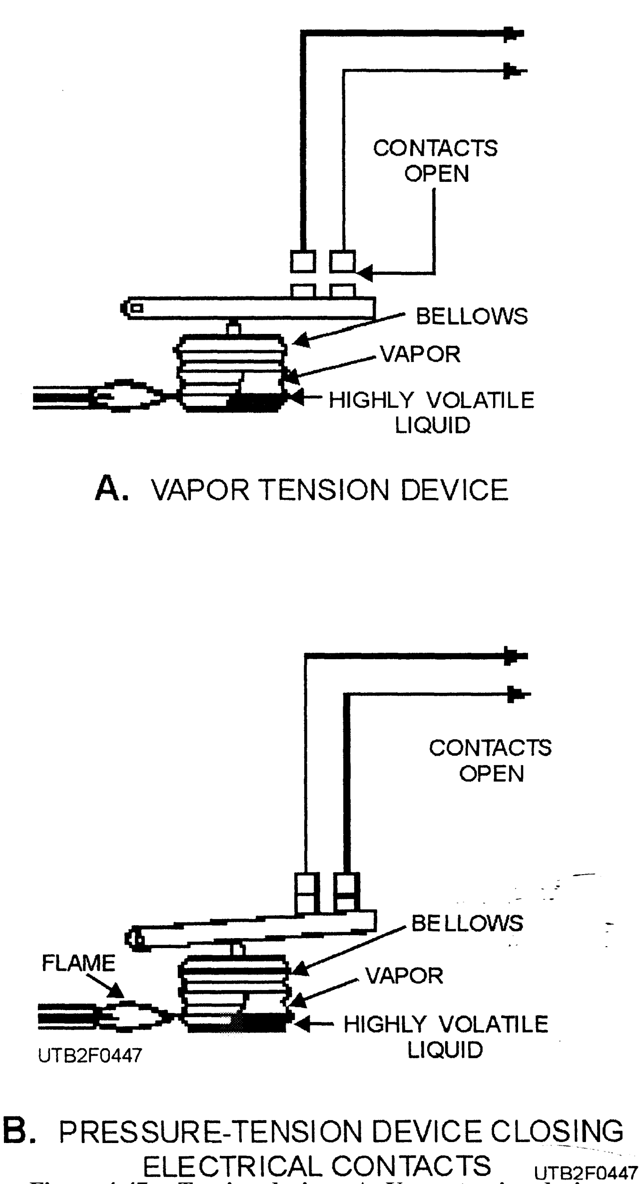

Figure 4-47.—Tension devices: A. Vapor-tension device; B. Pressure-tension device closing electrical contacts.

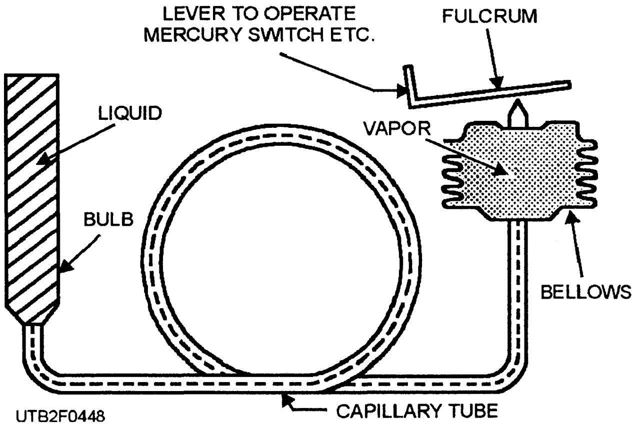

Figure 4-48.—Schematic of a remote-bulb device.

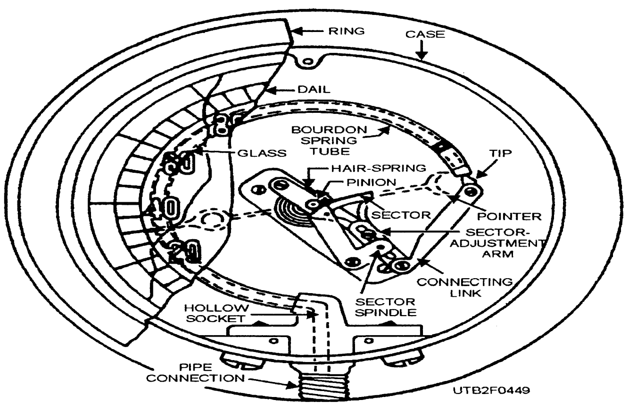

Figure 4-49.—A typical Bourdon spring tube.

hollow, partially flattened, bent tube, called a Bourdon spring tube. The pressure inside this tube tends to straighten it, and in so doing, it moves the lever mechanism that turns the pointer. The pressure gauge measures the pressure in pounds per square inch (psi).

Humidity-responsive devices open or close solenoid or motorized valves, which control the flow of water or steam to humidifying equipment. The sensitive element, which actuates the motion in this device, consists of a group of human hairs. These hairs lengthen when the humidity is high and shorten when the humidity is low.

Accumulation of dust and grease on these hairs, while not damaging, may decrease the sensitivity of the controller. Consequently, the element should be cleaned periodically with a camel's-hair brush and clean ether. A complete wetting with distilled water should follow this cleaning.

Electrical Switches.—Electrical switches in heating control equipment operate electrical circuits in response to signals from automatic control units. In other words, the actions initiated by devices responsive to temperature, pressure, and humidity changes open or close switch contacts. These, in turn, control the operation of the heating plant through electrical circuits. Switches may be either the snap-action type or the mercury type.

Snap-action switches vary in their designs.-Some are constructed so they have an over-center spring arrangement that is designed so the movement of the actuating lever engages the spring and causes the switch to move with snap-action. The snap-action type of switch is shown in figure 4-50, view A.

Another snap-action switch shown in figure 4-50, view A, has a small magnet that causes the electrical contacts to remain firmly closed. It also provides the switch with the snap-action effect. The contacts of this switch must open or close quickly to avoid excessive arcing across the points. Arcing burns the contacting surfaces, which eventually causes switch failure.

A mercury switch has the electrical contacts and a small amount of mercury in a hermetically sealed short glass tube, as shown in figure 4-50, view B. Tilting the switch causes the mercury inside the tube to cover or uncover the contacts. When the contacts are covered, the electrical circuit is completed.

Every electrical switch is designed so it has a specific rated capacity in amperes and volts; for example, a capacity of 8 amperes at 110 volts. An electrical switch should never be overloaded because overloading causes overheating, which eventually results in switch failure that can create a fire hazard.

The standard controls furnished for automatic fuel-burning equipment come in sets designed for warm-air, hot-water, and steam-heating systems. A standard set usually consists of a thermostat, limit control, primary control, and electric motor. Auxiliary controls are those designed for a specific function in a warm-air, hot-water, or steam-heating system. They are in addition to the standard controls.

Thermostat.—The thermostat is the nerve center of the heating-control system. It is the sensitive unit that responds to changes in room temperature. It indicates whether more or less heat is required from the

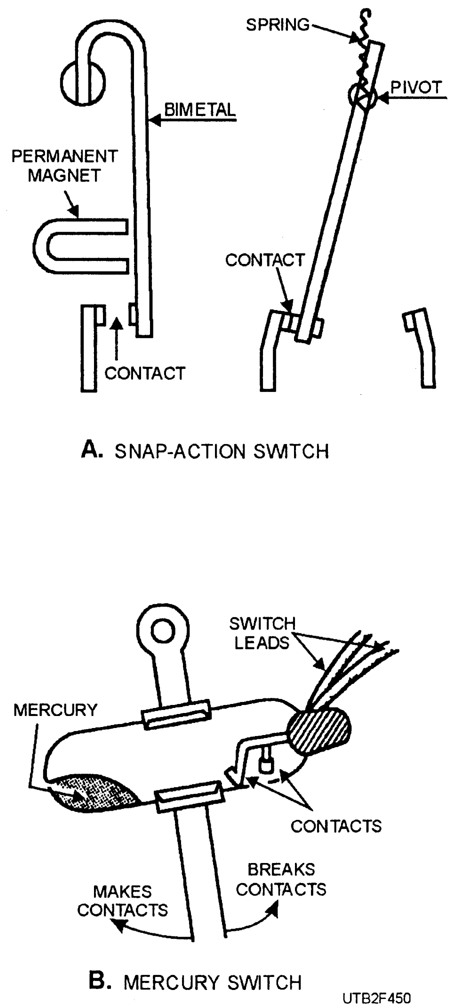

Figure 4-50.—Electrical switches: A. Snap-action switch; B. Mercury switch.

heating plant. It transmits the indicating signal to a primary control for action. This indicating signal is initiated by closing or opening electrical contacts in the thermostat.

Thermostats often differ in construction according to the type of primary control with which they are to be used. Probably the most used thermostats are the spiral-bimetallic type and the mercury-bulb type.

An electric clock thermostat has the additional features of an electric clock and an automatic mechanism that can be adjusted to change the thermostat setting at a desired time. For instance, it can be adjusted to reset the thermostat automatically from 80°F to 60°F at 11:00 p.m. (when 80°F heat is not needed). Then it will reset the thermostat to 80°F at 6:00 a.m. (when more then 60°F heat is needed).

The location for the thermostat should be representative of that part of the building in which heat is needed to maintain a comfortable temperature. The best location is on an inside wall, just a few feet from an outside wall and about 4 1/2 feet above the floor. The thermostat wiring must conform to local electrical ordinances.

To check the calibration of a thermostat, hang-an accurate test thermometer within 2 inches of the device. Allow 15 to 30 minutes for the thermostat and thermometer to adjust themselves to room temperature. The thermostat contacts should close when the control knob or dial is set at the temperature indicated by the test thermometer. You should not try to recalibrate the thermostat if the closing point varies 1°F or less. When calibration is necessary, follow the manufacturer's instructions.

FURNACE INSTALLATION

Since there are many types and makes of oil- and gas-fired warm-air furnaces on the market, detailed assembly instructions to suit all makes and types cannot be given in this manual. However, some general instructions, which apply to both oil-fired and gas-fired furnaces, except as noted, are given below.

Carefully follow assembling instructions included with each furnace or blower shipment. Each piece or casting is manufactured to fit in its proper place. Parts are seldom interchangeable.

Install furnaces in a level position. If the floor is uneven, use a steel wedge, a cast-iron wedge, or the leveling bolts provided on some equipment. Use a spirit level to make sure the unit is level.

Gas-fired and oil-fired forced-air units, which have the blower below the heating element or combustion chamber, should be set on masonry at least 3 inches thick and extending at least 12 inches beyond the casing wall. Install all other units on a cold masonry floor. Provide enough clearance to permit easy access for repairs. Make the clearance at least 18 inches from wood or other combustible material unless you install an asbestos board at least 1 inch from the combustible material. Units may be installed near masonry walls; however, leave ample room to permit proper servicing.

Furnace cement is furnished with each cast-iron furnace. Seal all furnace joints with a liberal amount of furnace cement between sections to ensure the furnace is gastight. Asbestos rope is furnished with a number of furnaces; follow the manufacturer's instructions covering its use. See that projections from the furnace, such as the smoke pipe or clean-out doors, extend through the outside of the casing.

In assembling a furnace, be sure to tighten all bolts. Draw each bolt until it is almost tight. Then, after all bolts have been installed, draw each one gradually until all are uniformly and properly tight. Avoid drawing bolts too tight, as this can crack or break a casting or buckle a steel plate.

After assembling the furnace, check all doors for free operation and tight fit.

Install the downdraft diverters furnished with the equipment on all gas-burning furnaces. Diverters are developed for individual furnaces.

Use a vent or smoke pipe that is at least as large as the smoke-pipe outlet of the furnace.

Securely fasten the vent or smoke pipe at each joint with a minimum of three sheet metal screws. Install horizontal pipe with a pitch upward of at least l-inch per linear foot (fig. 4-51).

Ventilate the furnace room adequately to supply air for combustion. Provide an opening having 1 square inch of free-air area for each 1,000 Btu per hour of furnace input rating with a minimum of 200 square inches. Locate the opening at or near the floor line whenever possible. In addition, provide two louvered openings, each having a free-air area of at least 200 square inches in it, at or near the ceiling as near opposite ends of the furnace room as possible.

Tank installation is largely governed by local conditions. Listed here are the principles of tank installation that give greatest freedom from service problems. Adhere as closely to these recommendations as local conditions permit.

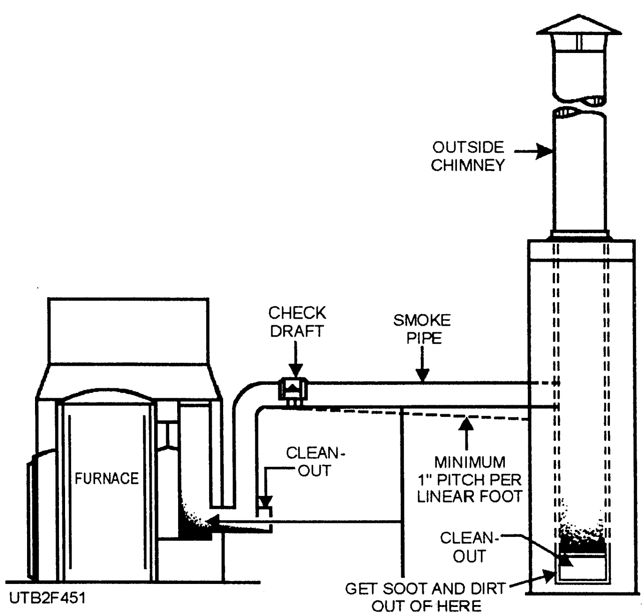

Figure 4-51.—Typical smoke pipe (flue) installation.

When possible, install single-pipe gravity oil feed on inside tanks or elevated outside tanks (fig. 4-52). This type of installation is used for single-stage pumps. Use a 1/4-inch globe valve at the tank instead of a larger size. Larger valves sometimes cause tank hum.

For all installations, use a continuous piece of 1/2-inch copper tubing from the oil tank or valve to the burner and a similar piece for the return when required. The principle is to minimize the number of joints and thus minimize the possibility of air or oil leaks.

For inside installations where it is necessary to run the piping overhead between the tank and burner, when the burner is either above or below the tank level, the two-pipe system is recommended. This requires the use of a two-stage pump.

A dual-stage pump may be changed from a single-stage to a two-stage pump to accommodate a single-pipe or two-pipe system. The stages on a Webster fuel pump can be changed by removing the four screws on the pressure side of the pump and lining the Number 1 up with the letter on the pump body for a one-pipe system. The Number 2 lined up with the letter is for a two-pipe system. Most Sunstrand fuel pumps are shipped from the factory set up for a one-pipe system. To change to a two-pipe system, remove the 3/8-inch pipe plug from the bottom of the pump housing. There you will find an Allen head plug. Remove this plug for a two-pipe system.

Install the outside tanks (fig. 4-53) according to the instruction below.

Normally, when you are installing an underground fuel tank, the suction and return lines are made of black iron from the tank to the inside of the building, and there the burner is connected by copper tubing with a coil in it (not shown in the illustration) to eliminate vibration.

The return line is usually installed in the opposite end of the tank. Carry it to within 5 inches of the bottom. This creates an oil seal in the two lines, and any agitation caused by return oil is safely away from the suction line.

A 1 1/2-inch fill line and a 1 1/2-inch vent line are recommended. Carry the vent well aboveground and put a weatherproof cap on it. Pitch the vent line down toward the tank.

Use special pipe dope on all iron pipe fittings that carry oil. Treat the underground outside tank and piping with a standard preparation or commercial corrosion-resistant paint.

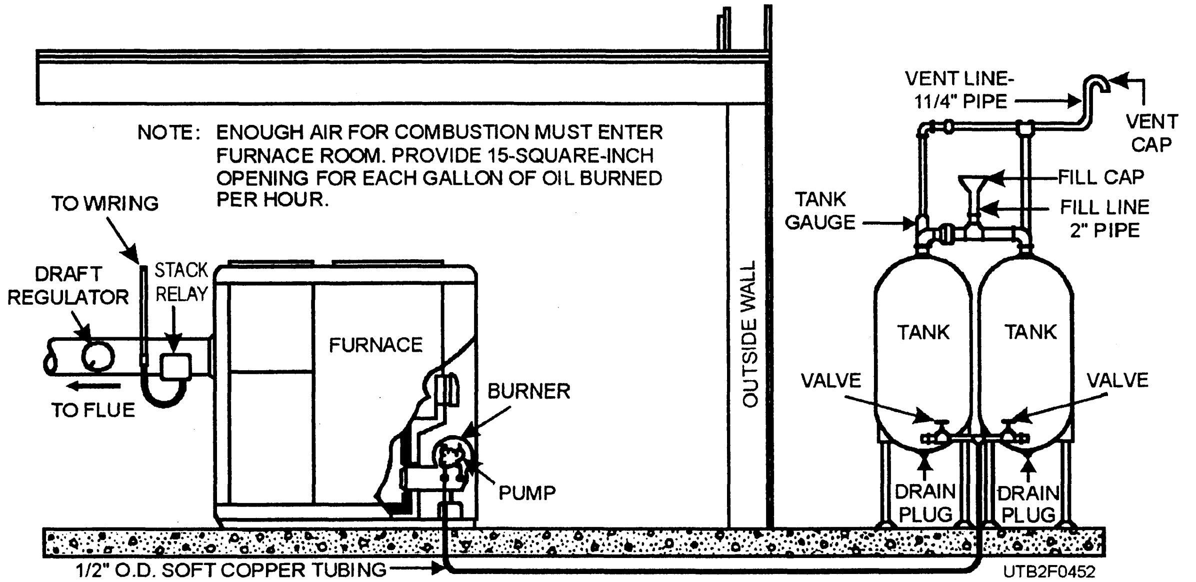

Figure 4-52.—Diagram of piping for inside or outside elevated tank installations.

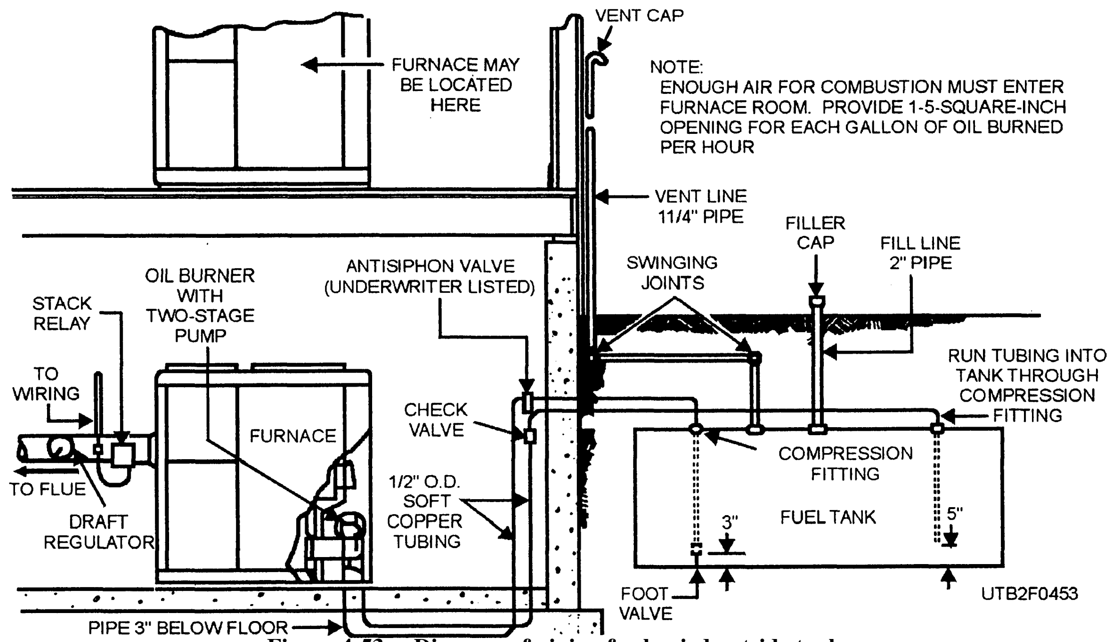

Figure 4-53.—Diagram of piping for buried outside tank.

MAINTENANCE OF FUEL OIL SYSTEMS

Among the major duties of the Utilitiesman are troubleshooting and servicing oil burners. To keep the burner in good operating condition, you must be able to recognize the symptoms of various types of trouble and must know how to make various service and maintenance adjustments to the burner.

Before getting into a discussion on trouble-shooting and servicing of oil burners, let's point out some information on fuel oil firing.

Fuel Oil Firing

Because fuel oils do not burn in the liquid state, several physical conditions must be attained to affect complete and efficient combustion.

1. Either the liquid must be thoroughly vaporized or gasified by heating within the burner, or the burner must atomize it so vaporization can occur in the combustion space.
2. The mist must be thoroughly mixed with sufficient combustion air.

3. Required excess air must be maintained at a minimum to reduce stack thermal loss.

4. Flame propagation temperature must be maintained.

Vaporization within the burner is generally confined to small domestic services, such as water heating, space heating, and cooking, and to some industrial processes. Burners for this purpose are usually of the pot type with natural or forced draft, gravity float-type feed control, and hand or electric ignition. Kerosene, diesel oils, and commercial oils of grades Nos. 1 and 2 are suitable fuels because they vaporize at relatively low temperatures.

If oil is to be vaporized in the combustion space in the instant of time available, it must be broken up into many small particles to expose as much surface as possible to the heat. This atomization is done in three basic ways:

1. By using steam or air under pressure to break the oil into droplets
2. By forcing oil under pressure through a suitable nozzle
3. By tearing an oil film into tiny drops by centrifugal force

Primary combustion air is usually admitted to the furnace through a casing surrounding the oil burner. The casing is spiral-vaned to impart a swirling motion to the air, opposite to the motion of the oil. Three types of burners used for atomization are the steam- or air-atomizing burner, the mechanical-atomizing burner, and the rotary-cup burner.

Burners should be piped with a circulating fuel line, including cutout, bypass, pressure-relief valves, and strainer ahead of the burner. Burners should be accessible and removable for cleaning, and the orifice nozzle plates should be exchan geable to compensate for a wide range in load demand.

Steam-Atomizing and Air-Atomizing Burners

The burners consist of a properly formed jet-mixing nozzle to which oil and steam or air is piped. The conveying medium mixes with fine particles of fuel passing through the nozzle, and the mixture is projected into the furnace. Nozzles may be of the external or internal mixing type, designed to project a flame that is flat or circular and long or short. A burner should be selected to give the form of flame that is most suitable for furnace conformation. Nozzles should be positioned so there is no flame impingement on the furnace walls and so combustion is completed before the i-lame contacts the boiler surfaces.

Steam-atomizing burners are simpler and less expensive than the air-atomizing type and are usually used for locomotive and small power plants. They handle commercial grade fuel oils Nos. 4, 5, and 6 and require a steam pressure varying from 75 to 150 psi. The oil pressure needs to be enough to carry oil to the burner tip, usually from 10 to 15 psi. Burners using air as the atomizing medium are designed for three air pressure ranges: low pressure to 2 psi, medium pressure to 25 psi, and high pressure to 100 psi.

Figure 4-54 shows a steam-atomizing burner of the external mixing type. In view (A), the oil reaches the tip through a central passage and whirls against a sprayer plate to break up at right angles, view (B), to the stream of steam. The atomizing stream surrounds the oil chamber and receives a whirling motion from vanes in its path. When air is used as the atomizing medium in this burner, it should be at 10 psi for light oils and 20 psi for heavy oils. In view (C), combustion air enters through a register; vanes or shutters are adjustable to give control of excess air.

Mechanical-Atomizing Burner

The burner is universally used except in domestic or low-pressure service. Good atomization results when oil under high pressure (to 300 psi) passes through a small orifice and emerges as a conical mist. The orifice atomizing the fuel is often aided by a slotted disk that whirls the oil before it enters the nozzle.

Figure 4-55 shows a mechanical-atomizing burner. View (A) is a cross section of the burner; view (B) shows the central movable control rod that varies, through a regulating pin, the area of tangential slots in the sprayer plate and the volume of oil passing through the orifice; view (C) shows a design with a wide-capacity range, obtained by supplying oil to the burner tip at a constant rate in excess of demand. The amount of oil burned varies with the load; the excess is returned.

Horizontal Rotary-Cup Burner

The burner (fig. 4-56) atomizes fuel oil by tearing it into tiny drops. A conical or cylindrical cup rotates at high speed (about 3,450 rpm), if motor driven. Oil moving along this cup reaches the periphery where centrifugal force flings it into an airstream. It is suitable for small low-pressure boilers.

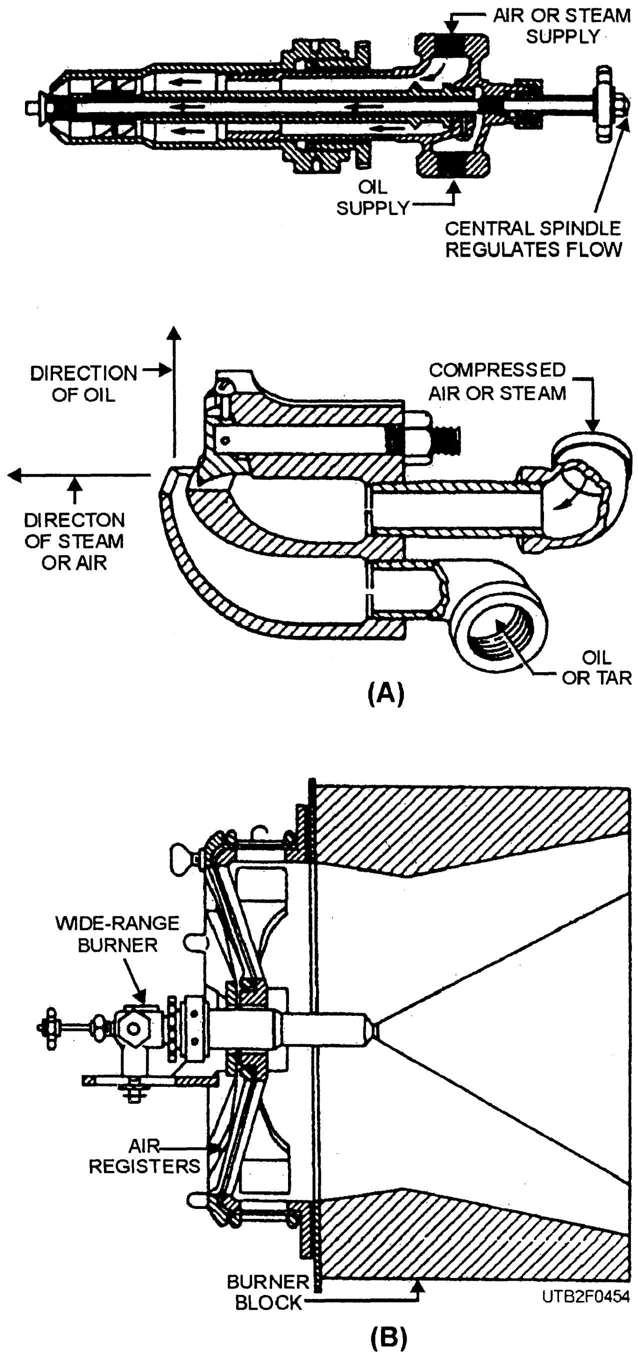

Figure 4-54.—Steam-atomizing burner.

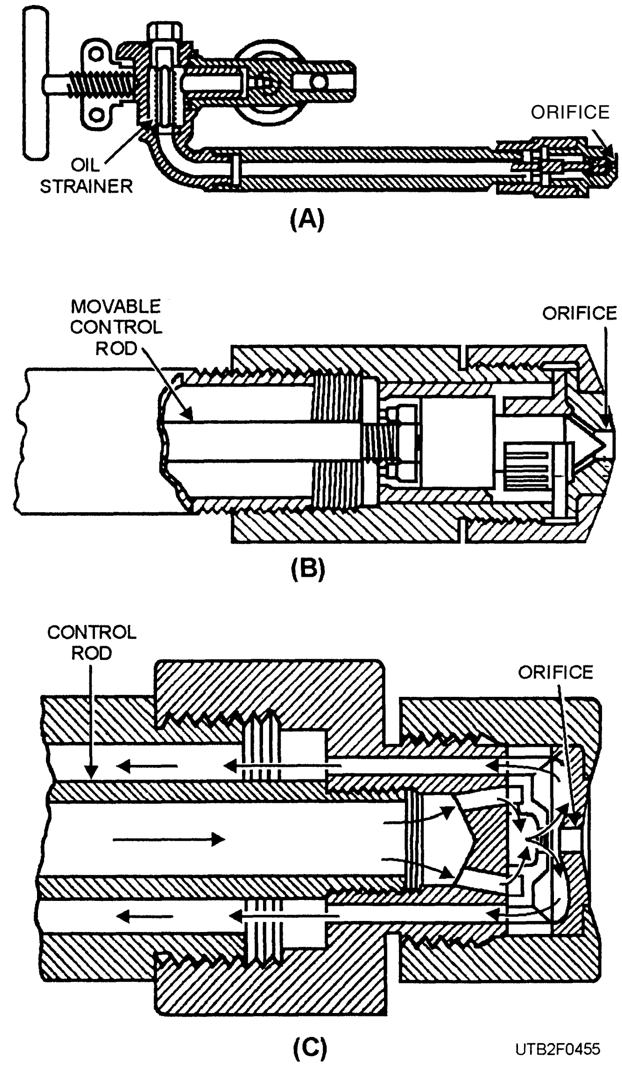

Figure 4-55.—Mechanical-atomizing burner.

OIL-BURNER MAINTENANCE

Before attempting to start or to service oi I burners, see that you have the proper maintenance equipment available. One item of equipment needed is a pressure gauge set. This should consist of a 150 psi pressure gauge, fittings to connect it, and a petcock for removing the air from the oil line when starting the burner. You will need a full set of Allen setscrew wrenches for bypass plugs and for adjusting the nozzle holder and electrodes. Make sure you have a socket wrench of proper size for removing or replacing the nozzle, an open-end wrench as required for the nozzle holders, and a small thermostat wrench. This wrench comes packed with the thermostat and is used for adjusting the differential. A small screwdriver is required for adjusting pressure at the regulator and installing and servicing the thermostat. Another important item is pipe dope, and if available, use the oil-line type only. If in doubt, order a can of special oil-pipe dope for use on all pipe threads requiring dope. A nozzle assortment should also be kept on hand. It is cheaper to make a change, time considered, than to clean the nozzle on the job. When a few nozzles have accumulated, clean them in the shop.

When installing a nozzle, use a socket wrench for turning the nozzle. Be sure the nozzle seat is clean. Screw it on until it reaches the bottom, then back it off and retighten it several times to make sure of a tight oil seal. Do not overtighten the nozzle or the brass threads will become deformed, making it difficult to remove the nozzle.

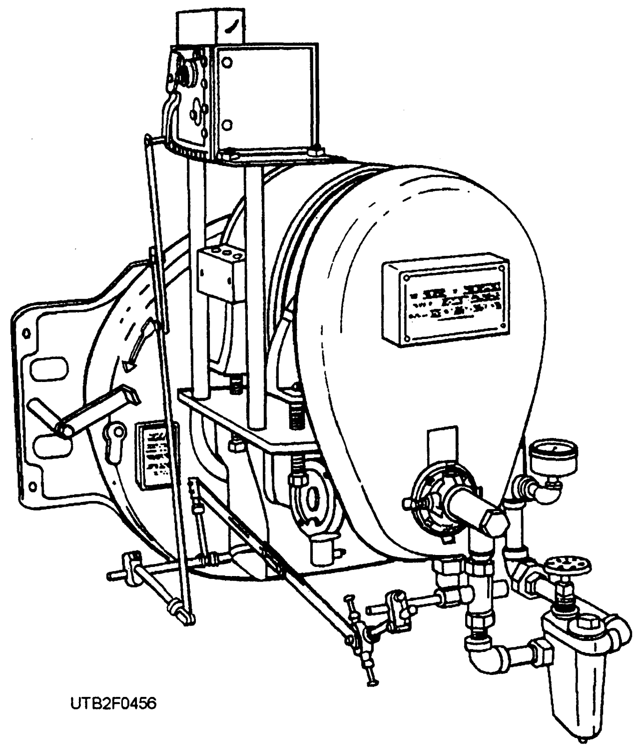

Figure 4-56.—Rotary-cup oil burner.

Clean the nozzles in the shop on a clean bench. A nozzle is a delicate device. Handle it with care. Use kerosene or safety solvent to cut the grease and gum; use compressed air, if available, to blow the dirt out. Use goggles for eye protection when blowing dirt out with compressed air. Never use a Jnetal needle to clean the opening; it will ruin the nozzle. Sharpen the end of a match or use a nonmetallic bristle brush to clean the opening.

When you are checking the nozzle, adjustments may have to be made in the distance of the nozzle from the tube end, the distance of the ignition points ahead of and above the nozzle, and the distance or gap between the ignition points. Figure 4-57 shows these nozzles adjustments. The nozzle tip is set 5/8 inch apart, 1/8 inch ahead of the nozzle, and 1/2 inch above the nozzle center line. These settings are given only for this particular illustration. Actual adjustments should always be made according to the specific settings in the manufacturer's instruction manual. Always tighten electrodes securely to ensure permanent adjustment.

When reinstalling either the pump or the motor, check the coupling to ensure there is no end pressure on the pump shaft as evidenced by lack of end play. If there is end pressure, the coupling should be loosened, moved closer to the pump, and re-tightened.

Troubleshooting

When oil burners are operated, operating problems will occur. These problems can cause interruption of service, inefficiency, and damage to the equipment in the system. To ensure proper operation and efficiency, you will need to be able to identify and correct these difficulties. A list of common difficulties and their remedy are contained in appendix II, table L.

Flame Adjustment

After the burner has been visually adjusted and allowed to run about 30 minutes, reduce the stack draft until there is just enough over-fire draft in firebox to keep the pressure from increasing under unfavorable draft conditions. The draft regulator helps Jnaintain a constant draft in the furnace regardless of outside weather conditions. Adjust the draft by properly setting the ad-juster. Too little draft is likely to cause firebox pressure, odors in the building, and possible smoke or smothering of the flame. Too much draft accentuates the effect of a possible leak in the furnace, lowers the percentage of CO_2 in the flue gas, and, in turn, reduces the overall efficiency of the unit. After the burner flame and draft are properly adjusted, a flue-gas analysis should show a CO_2 content of approximately 10 percent. If it does not, recheck the burner air adjustment and inspect for air leaks. For best results, the flame should be just large enough to heat the building properly in cold weather.

Air supplied to the burner will then be the minimum for clean combustion. If the furnace is large enough and the burner has been set for correct oil flow and minimum amount of air, stack temperature should not exceed 600°F. Higher stack temperatures indicate that the fire is too large or the furnace too small, or that there is too much excess air.

Test Equipment

It is almost impossible to set and adjust a burner without instruments or test equipment. Proper instruments, in good working order, must be available in the heating shop for use by personnel who service this equipment.

The draft gauge, usually of the pointer-indicating type, is used to determine suction in the smoke pipe or combustion chamber. Suction is measured in inches of water. Carefully follow the instructions for operating the instrument.

The stack thermometer is used to indicate the temperature of gases in the smoke pipe. Insert the

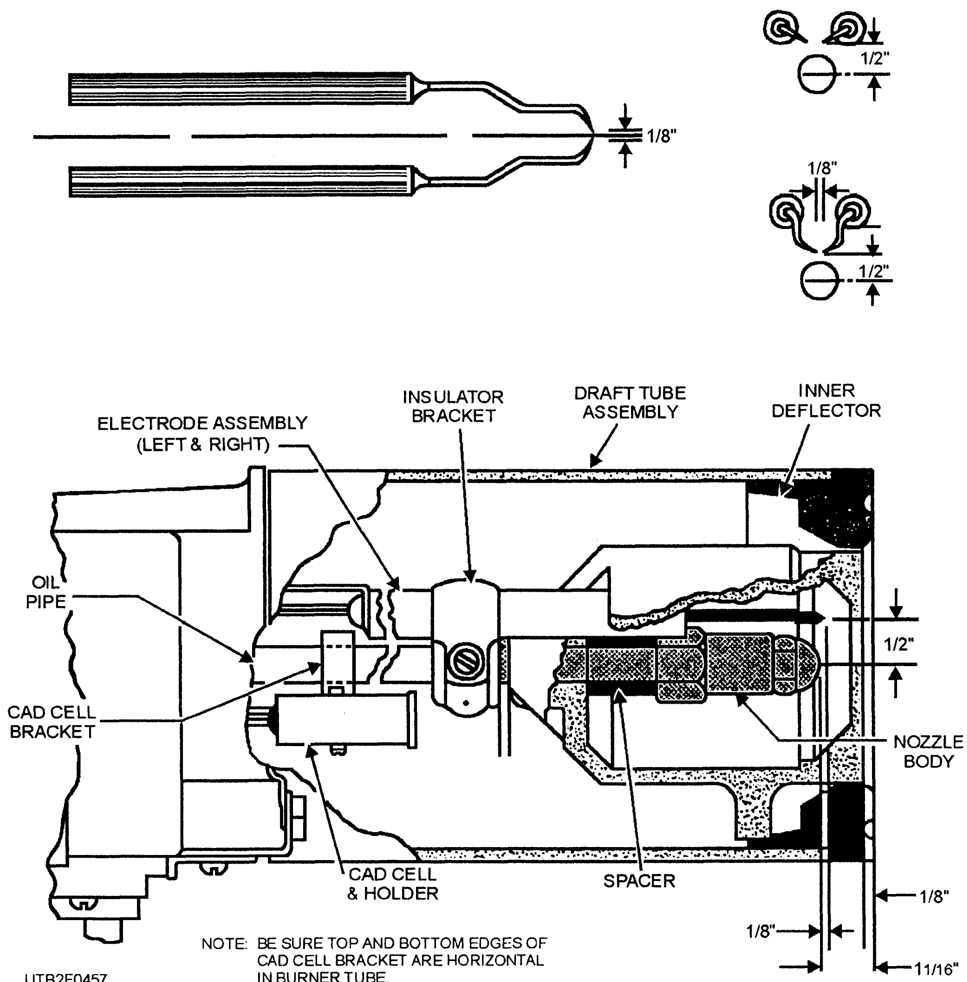

Figure 4-57.—Setting of ignition points and nozzle.

thermometer halfway between the center and outside of the smoke pipe and not more than 12 inches from the furnace between the smoke pipe connection and the draft regulator or barometric damper. Be careful to prevent the thermometer from being influenced by cold air taken in by the draft regulator.

The flue-gas analyzer is used to determine the percentage of CO_2 produced by combustion. The CO_2 reading shows how much excess air is being used. Along with the stack temperature, it denotes the efficiency of the furnace. If, despite a good flame setting, CO_2 readings are low, examine the furnace for air leaks.

FUEL PUMP

Maintenance requirements include cleaning the strainer, servicing the valve seat and needle valve, and adjusting the pressure regulator. Strainers must be cleaned frequently to prevent the screen from clogging and causing a shutdown. A good test for valve operation consists of removing the nozzle line at the pump connection, starting and stopping the pump, and observing whether the valve cuts off sharp and lean. When necessary, the valve is easily serviced by removing the valve chamber cover, holding spring, washer, adjusting spring, cap, and bellows assembly. Then, by taking off the nut that is marked "Nozzle," the valve, valve guide, and plug assembly can be removed.

Adjustment of the pressure regulator can be done by replacing the vent plug with a pressure gauge, removing the cover screw, and using an Allen wrench to turn the adjusting screw clockwise to increase the pressure or counterclockwise to decrease the pressure.

Burner failure or improper unit operation can be caused by various problems. Often the problem can be pinpointed by observing the type of failure and giving it some thought before attacking the problem. At other times, the cause can only be determined by a process of elimination. Table M in appendix II lists specific oil pump troubleshooting procedures, while table K, also in appendix II, lists general oil burner troubleshooting procedures. Check the simplest and more obvious items before progressing to the other checks.

Q15. With warm-air systems, the amount of heat reaching each room is determined by what two factors?

Q16. What are the four airflow designs of gas-fired furnaces?

Q17. What safety device on gas-fired heating equipment reacts to the operation of the pilot flame?

Q18. What device shuts off the gas supply when the temperature inside the heating unit becomes excessive?

Q19. What are the three internal areas of an oil-fired furnace?

Q20. What device is the nerve center of the heating control system?

Q21. What are the two most commonly used types of thermostats?

Q22. A steam-atomizing burner requires a steam pressure of what range for atomizing?

Q23. Electrode adjustments should always be set on burners according to what publication?

Q24. What instrument is used to determine the percent of CO_2 produced by combustion?

DOMESTIC HOT-WATER HEATING AND HOT-WATER BOILERS

Learning Objective: Identify types of hot-water boilers, their fittings and accessories, and their operation.

The Navy uses both cast-iron and steel hot-water boilers as sources of heat for domestic hot-water systems in residences and other buildings. Small hot-water heaters heat the hot water for domestic and for limited industrial uses.

Hot-water boilers come in many shapes and sizes. They are constructed with a firebox for burning fuel and have provisions for passing the hot gases over the heat-absorbing surfaces of the boiler. In most cases, baffles guide the gases over the most effective route. These baffles also retard the flow of the gases from the furnace, so water can absorb as much of the heat as possible. Both ends of the boiler have openings for cleaning the boiler tubes and for washing the interior of the boiler. Since most boilers are stationary units permanently installed at the site, they have specified fittings and accessories for a specific heating job. Some boilers, however, called package boilers, are complete units, including fittings and accessories. These boilers are normally mounted on skids so they can be moved to different sites.

This accounts for the term *package boiler.* Package boilers usually have the same accessories and controls as the comparable stationary type of hot-water or steam boiler. Cast-iron boilers are seldom used as package boilers because of the danger of cracking the boiler sections during transportation.

Cast-iron hot-water boilers vary in size from small domestic units to moderately sized units capable of developing 31 through 98 horsepower. These boilers are usually constructed of several sections joined together by push nipples (round pieces of metal pipe tapered at both ends). Pipes, known as header connections (fig. 4-58) ordinarily connect the boiler sections.

Cast-iron boilers normally do not have brick settings. Usually, the only bricks used with these boilers are those that are sometimes used as a base for the boilers. In most cases, the bases are made of cast iron. Square sectional cast-iron boilers are similar to the typical unit shown in figure 4-59. This boiler consists of a front and rear section and a number of intermediate sections, depending on the size of the boiler. The sections are connected on each side at the top and bottom either by push nipples or by an outside header. When nipples are used, these sections are held firmly together by rods and nuts.

The boiler has a separate base that does not contain water and, therefore, requires a floor of fireproof construction. Boilers that have water in their bases are referred to as wet-bottom boilers. These boilers are relatively small water units that may be installed on floors constructed of combustible materials. This method of installation, however, is not desirable.

The construction of square sectional boilers is ordinarily such that the sections can be taken through regular-sized doors for assembly inside the boiler room. This is a distinct advantage from the standpoint of both installing new equipment and replacing broken sections. Cast-iron boilers resist the chemical action of corrosive agents much better than steel boilers.

The disadvantage of cast-iron hot-water heating boilers is the danger of the sections cracking or breaking when improperly handled or fired.

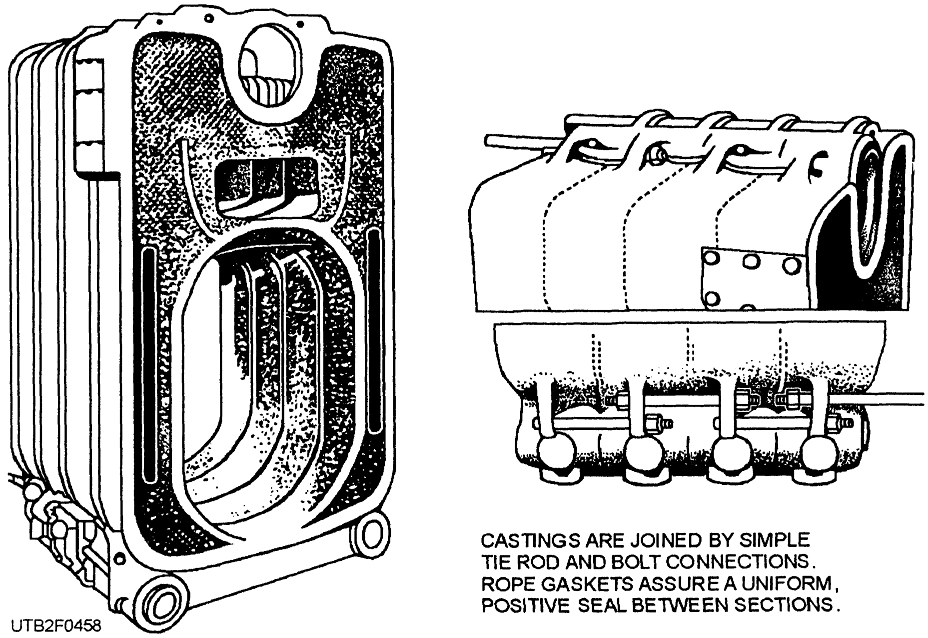

Figure 4-58.—Cast-iron boiler castings.

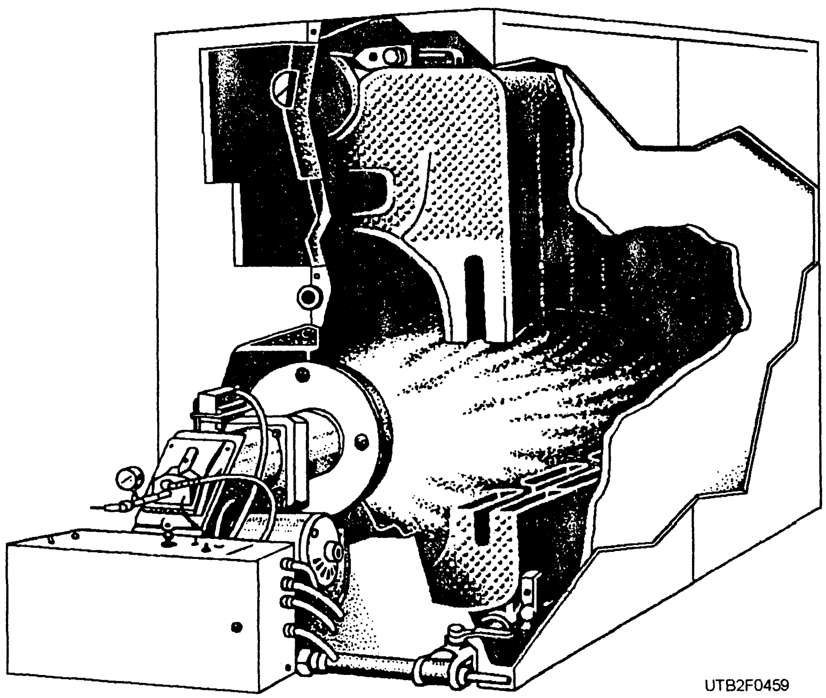

Figure 4-59.—Cutaway view of a cast-iron boiler.

STEEL HOT-WATER BOILERS

Most steel hot-water boilers are constructed in two sections. One section consists of the water jackets, combustion chamber, and smoke passages. These components are either welded or riveted together as a unit. The other section consists of the base and either the grates or burner and is constructed according to the type of fuel used (fig. 4-60).

Another steel boiler is a horizontal unit of the portable type, having an internal firebox surrounded by water lanes. It rests either on a cast-iron or a brick base. The front part of the boiler rests on a pedestal. A disadvantage of this one-piece steel boiler is that it is heavy and requires special equipment to lift it.

INSTALLING BOILERS FOR HOT-WATERHEATING

A boiler must have a good foundation. The top surface of the foundation should be level to ensure

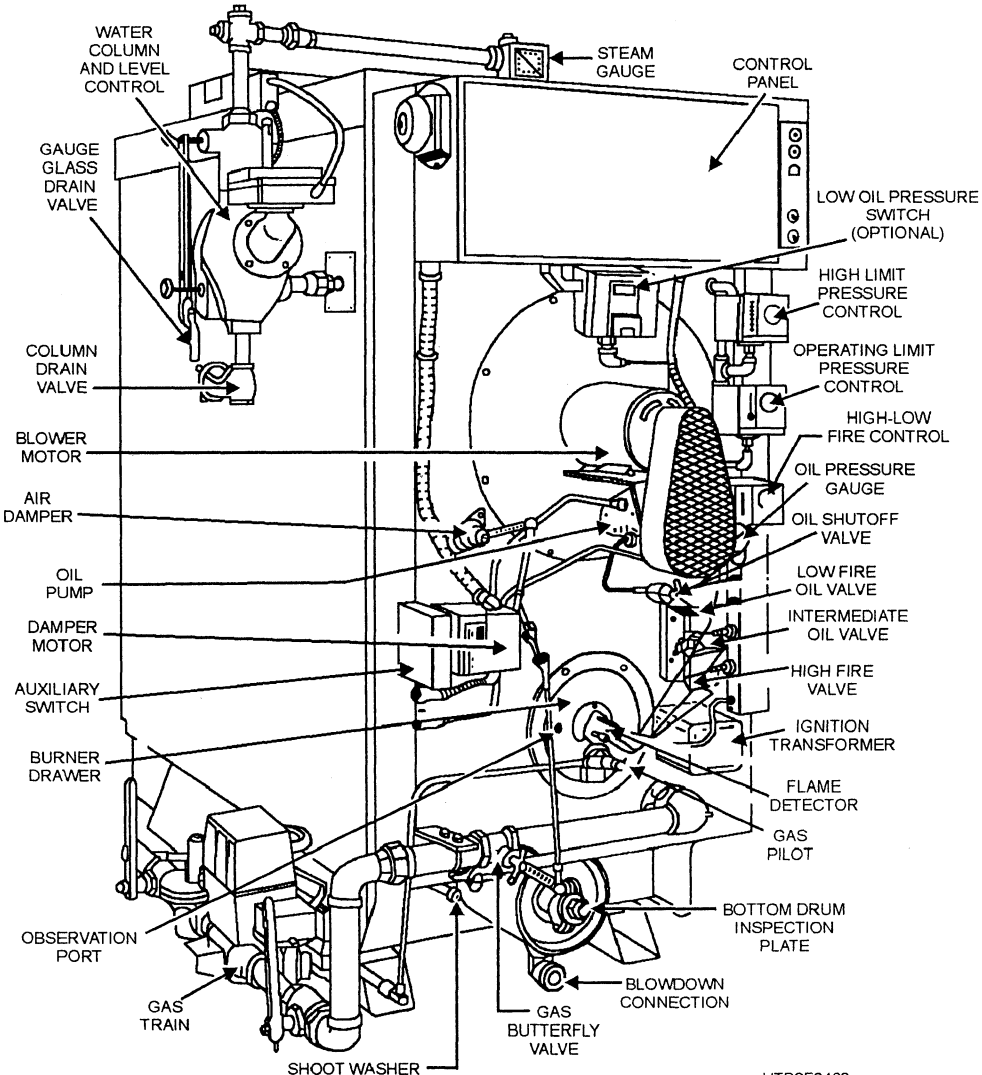

Figure 4-60.—Typical hot-water boiler-light oil or gas fired.

proper alignment of the boiler sections, and thus eliminate strain on the boiler castings. The furnace foundation should be poured separately from the finished floor. It should be of sufficient width and depth to support the boiler without any settling, and it should extend 2 inches above the finished floor. Assembly procedures vary in detail for various boilers. However, manufacturers furnish detailed procedures for the assembly of their boilers. Usually, the plans for the foundations can be procured from them.

OPERATION OF HOT-WATER BOILERS

Hot-water boilers, regardless of their design and type, operate on the same basic principle. The fuel burns in the combustion chamber and produces heat. The resultant heat is radiated and conducted to the water in the water jackets surrounding the combustion chambers and passes through the boiler tubes; heat is liberated by the flue gases and absorbed by the water surrounding the tubes. The amount of heat transferred into the water depends on the rate of heat conduction through the metal in the boiler tubes and the rate of water circulation in the boiler. For this reason, boilers are designed with baffles to hold the hot gases as long as possible. They give up maximum heat before passing into the chimney.

BOILER FITTINGS AND ACCESSORIES

All boilers have certain accessories for safety and ease of operation. These accessories are pressure-relief valves, pressure gauges, water-level control valves, and automatic controls.

Pressure-Relief Valve

In a closed hot-water heating system, there is always the possibility of building up a dangerous pressure. Consequently, a pressure-relief valve is installed to allow this pressure to escape. A typical pressure-relief valve is shown in figure 4-61. This valve is usually on the top of the boiler. It contains a spring-loaded valve that unseats when the pressure in the system increases to a predetermined value, thereby allowing water to escape until the pressure drops to a safe point. A valve of this type can be adjusted for different pressure.

Pressure-relief valves may eventually corrode and stick if they are not forced to operate occasionally. It is a good practice, once each month, to increase the pressure to a point that operates the valve. When the relief pressure on the gauge exceeds the setting of the valve, check the valve pressure with an accurate gauge and adjust it to the required amount. However, do not exceed the maximum safe pressure of the boiler.

Pressure Gauge

The operator must know the water pressure in the boiler at all times. A gauge is connected to the top of the boiler. It shows the water pressure in the boiler and in the system in pounds per square inch. This gauge is usually a combination gauge that also indicates boiler water temperature and altitude. The type shown in figure 4-62, however, indicates pressure only.

Little maintenance is required for this unit other than to clean the glass so the gauge can be read. Some types of pressure gauges are constructed so they can be re-calibrated. However, the proper equipment to do this is not always available in the heating shop. To calibrate a pressure gauge properly, you must have either a master gauge set or a deadweight tester.

Water-Level Control Valve

Water is added to a hot-water heating system by either a manually operated water valve or an automatic valve, which is controlled by a float mechanism. Both valves are nearly identical to those used in the free-water system of a steam boiler.

Airflow Switch

The airflow switch, or "sail switch" as it is sometimes called, is in the stack, breeching, or the air inlet to the boiler. This switch shuts down the firing equipment in the event of an induced or forced draft failure. To check the operation of this switch, you restrict or shut off the draft. When you have done this, the switch should shut off the burning equipment.

Q25. It is a good practice to test the pressure relief valve by what method and what frequency?

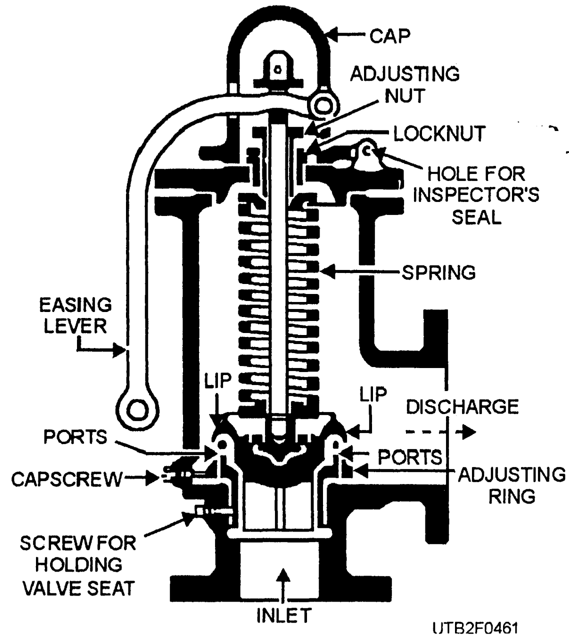

Figure 4-61.—A typical pressure-relief valve.

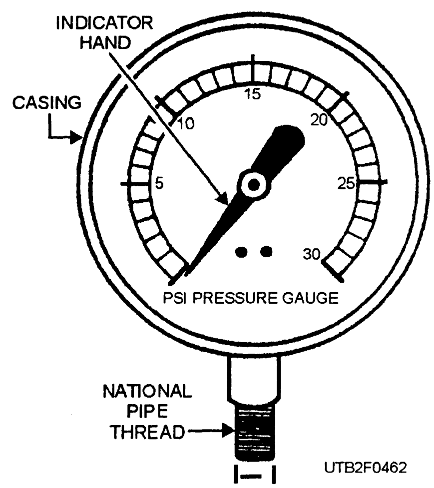

Figure 4-62.—A typical water pressure gauge.

Q26. What is the name sometime used to refer to an airflow switch?

HOT-WATER HEATING DISTRIBUTION SYSTEMS

Learning Objective: Identify types of hot-water distribution systems and components. Understand the operation and maintenance of these systems.

In hot-water heating systems, the water is heated at a central source and circulated through pipes to radiators, convectors, or unit heaters. There are two general types of low-temperature, hot-water heating systems. The first type is a gravity system in which water circulation depends upon the weight difference between the hot column of water leading to the radiators and the relatively cooler, heavier column of water returning from the radiators. The second type is the forced-circulation system in which water is circulated by a power-driven pump.

GRAVITY SYSTEMS

The distribution systems and piping for hot-water heating systems and for domestic hot-water supply systems are simpler in design than those for steam because there are no traps, drips, or reducing valves. Several items, such as supports, insulation, and some valves and fittings, are the same for steam and hot-water distribution.

Gravity hot-water distribution systems operate because of the gravitational pull on the heavier cool water, which sinks as the heated water becomes lighter and rises. At this point, some of the types of gravity systems that are currently used are discussed.

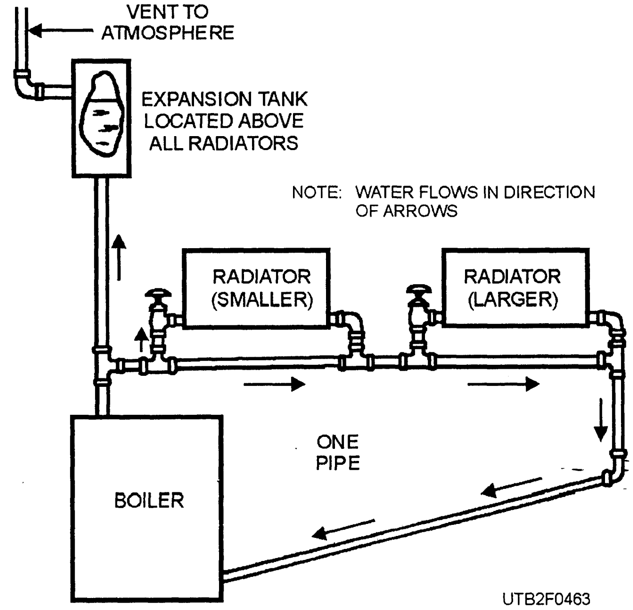

Figure 4-63.—A one-pipe, open-tank gravity hot-water distribution system.

One-Pipe, Open-Tank System

The one-pipe, open-tank gravity distribution system shown in figure 4-63 consists of a single distribution pipe that carries the hot water to all of the convectors or radiators and returns it to the boiler. This system is easy to install and moderate in cost.

The water that flows into the radiators at the end of the system has a lower temperature than the water entering the first radiators. A system of this type should be designed so the water reaching the last convector is not too much cooler than the water reaching the first convector. Because of this progressive temperature drop in the distribution system, convector radiators should be installed at the end of the system to equalize the amount of heat radiation per radiator. It is difficult to get enough circulation by gravity to give the system small convector temperature drops; consequently, we do not recommend the one-pipe, open-tank gravity system.

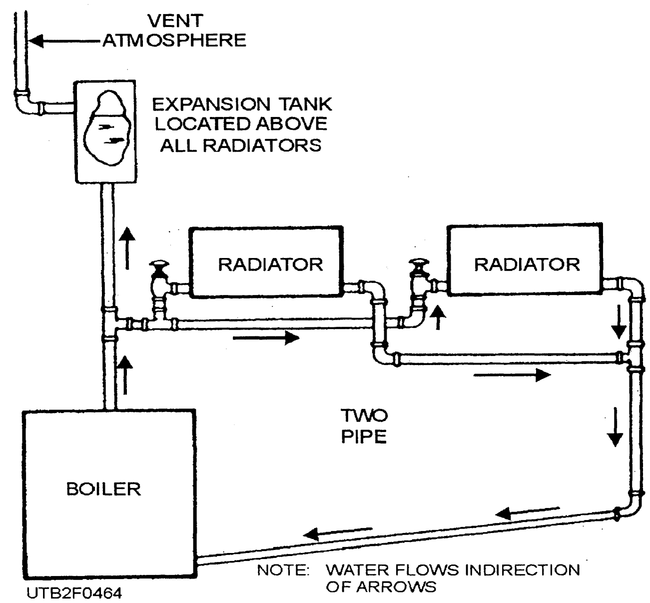

Figure 4-64.—A two-pipe, open-tank gravity hot-water distribution system.

Two-Pipe, Open-Tank System

Many hot-water gravity distribution systems are two-pipe, open-tank systems, as shown in figure 4-64. This heating system is constructed with separate water mains for supplying hot water and returning cold water. The radiators are connected in parallel between the two mains. In the two-pipe, open-tank gravity system, the distributing supply mains are either in the basement with upfeed to the radiators or in the attic. When the system is in the attic, it has overhead downfeed supply risers. The return mains are in the basement. Return connections for the two-pipe system are usually made into a gravity return, which pitches downward to the return opening in the heating boiler. The water temperature is practically the same in all radiators, except for the allowance to be made for the temperature drop in the distribution supply mains occurring between the boiler and the end of the circuit. Water temperatures are the lowest at the end of the circuit. The amount of temperature drop between the beginning and the end of the line depends upon the length of the main and upon the heating load.

A tank with its vent open to the atmosphere is installed in the system above the highest radiator for water expansion. The water level in the expansion tank rises and falls, as the system is heated and cooled, and the system is full of water and free from air at all times. In the open-tank gravity hot-water heating system, the expansion tank is installed on a riser directly above the boiler, so the air liberated from the boiler water enters the tank and is not retained in the system.

One-Pipe, Closed-Tank System

A one-pipe, closed-tank gravity hot-water distribution system, as shown in tigure 4-65, is similar to the one-pipe, open-tank gravity hot-water heating system, except the expansion tank is a pneumatic compression tank not open to the atmosphere. When the water in a closed-tank system is heated, it. expands into the pneumatic compression tank. This action permits system operation at a much higher water temperature, without boiling, than the temperature in the one-pipe, open-tank gravity system. This also results in higher heat emission from the radiators.

A gravity open-tank system with an average boiler water temperature of 170°F has a radiator emission rate of 150 Btu psi, whereas a gravity closed-tank system with an average boiler water temperature of 190°F has a radiator emission of 180 Btu per square foot (psf). Higher boiler water temperatures permit higher temperature drops through the radiators; consequently, smaller pipe sizes can be used. The closed pneumatic compression system requires a relief valve, usually set for the relief of water pressure over 30 psi, depending upon the height of the building. A pressure-regulating valve automatically maintains the system full of water. Installation of the radiators and piping for an equivalent two-pipe, closed-tank gravity upfeed or overhead downfeed system is the same as that for the open system, except the sizes of both the pipe and the radiators are uniform and can be smaller. The open-tank system may have a reversed return main that does not go directly back to the boiler.

It doubles back from the last radiator and parallels the supply main back to the boiler entrance. The reversed return system allows equal length of heating circuits for al I radiators. Friction and temperature losses for all radiators are nearly equal. In most cases, the reversed return system involves no more piping than other piping arrangements. With the correct size of piping and radiator supply tappings, the reversed return system provides even heat and circulation to all radiators, even those near the end of the circuit.

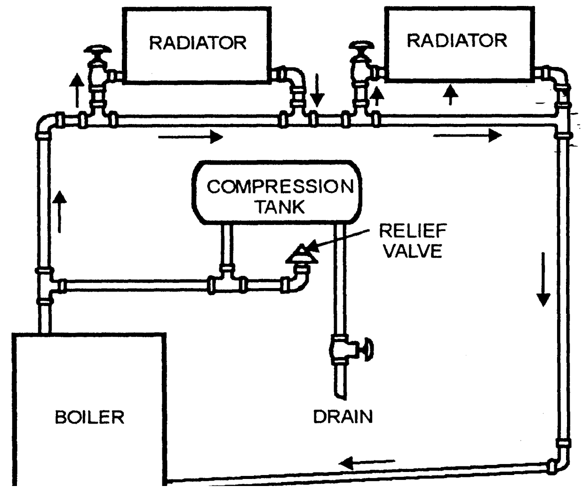

Figure 4-65.—A typical one-pipe, closed-tank distribution system.

Expansion in a Gravity Hot-Water Distribution System

In the gravity and forced-circulation systems, open and closed expansion tanks allow the water in the distribution system to expand as the temperature rises. An open tank must be mounted at the highest point in the system; a closed tank can be located at any point. If the air cushion leaks out of the closed expansion tank, it fills with water. At times, you must recharge the tank by draining part of the water out of the tank and allowing air to -fill the space.

In the open system, an expansion tank open to the atmosphere allows the system to expand. The open system is normally designed to operate at the maximum boiler temperature of 180°F. This gives an average radiator temperature of 170°F or a radiator output of 150 Btu psf. The closed system, in which the expansion takes place against a cushion of air in the tank closed against the atmosphere, can be operated at temperatures above 212°F because the pressure built up in the system prevents the water from boiling. Radiator temperatures then become equal to those of low-pressure steam systems.

When a hot-water system is first filled with water, it is normally necessary to bleed the air out of the system at the same time. You can remove the air by opening an air vent on a radiator or by breaking a union near the end of the line. The temperature of the water distributed is from 150°F to 250°F. The higher temperatures are used with the forced-circulation systems.

FORCED-CIRCULATION SYSTEMS

Forced-circulation hot-water distribution systems have several advantages. They permit the use of smaller pipe sizes and allow the installation of radiators at the same level as the boiler, or below, without impairing water circulation. By using a circulation pump, a positive flow of water is assured throughout the system. In larger installations, especially where more than one building is served, forced circulation is almost invariably used. With the development of a circulation pump of moderate cost, the forced-circulation system is being used more in small heating installations.

Even as in gravity systems, forced-circulation systems can consist of a one-pipe or a two-pipe, upfeed or downfeed, and can be equipped with a direct or a reversed return. Although these systems usually have closed expansion tanks, they may have open tanks.

One-Pipe, Closed-Tank System

The general arrangement of a one-pipe, closed-tank, forced-circulation system shown in figure 4-66 is similar to the one-pipe gravity system, but with the addition of a circulating pump.

The circulation to individual radiators is improved by special supply and return connecting tees. These tees, by an ejecting action on the distribution supply main and an ejecting action on the return, combine to use a portion of the velocity head in the main to increase circulation through the radiators. Tees of this type also aid stratification of hot and cold water within the distributing main. They are designed to take off the hot-test water from the top of the main and to deposit the colder water on the bottom of the main.

Two-Pipe, Closed-Tank System

The general arrangement of the piping and radiators for the two-pipe, forced-circulation distribution system is the same as that for the two-pipe gravity system. The relative locations of the compression tank relief valve and the circulating pump are shown in figure 4-67.

DISTRIBUTION SYSTEM COMPONENTS

The component parts of a hot-water distribution system are similar to that of steam heating systems as described in chapter 3. They include the following: pipelines, radiators, convectors, unit heaters,

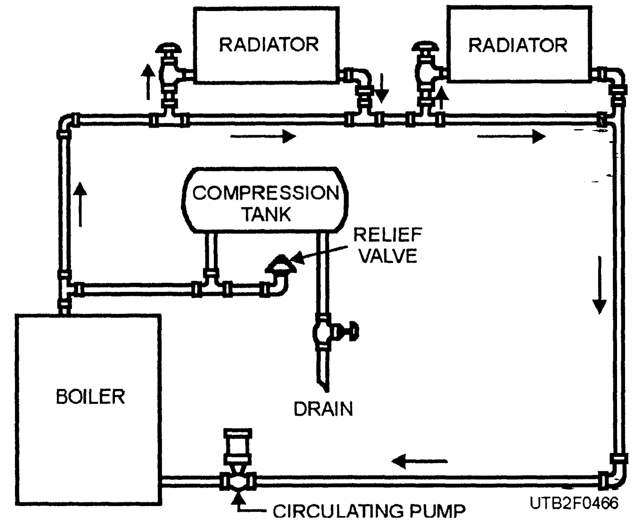

Figure 4-66.—A one-pipe, closed-tank distribution system with a circulating pump.

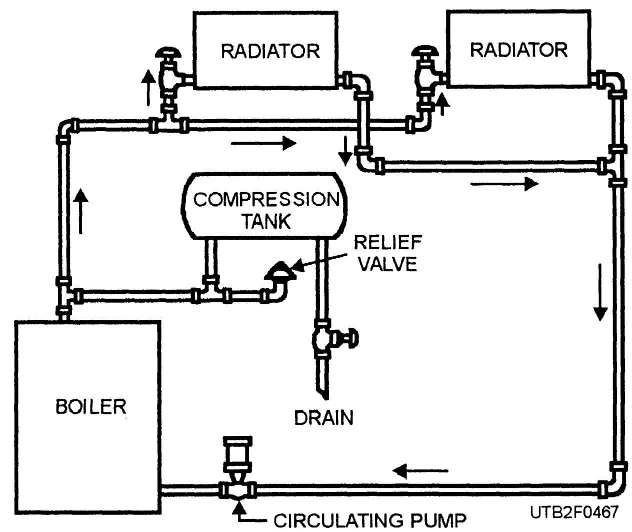

Figure 4-67.—A two-pipe, closed-tank, forced-circulation system.

circulating pumps, reducing valves, flow-control valves, and special tlow fittings.

Pipelines

The piping system constitutes the closed passageway for the delivery of hot water to the points where it is used. Pipelines are made of lengths of pipe fastened by screwed, flanged, or welded joints. They have valves and fittings, such as tees, unions, and elbows, according to the needs of the installation. Pipelines are supported by hangers and fastened by anchors. Expansion joints or loops allow for expansion.

Mains and branches of the pipeline should be pitched so the air in the system can be discharged through open expansion tanks, radiators, and relief valves. The pitch is generally not less than 1 inch for every 10 feet. The piping arrangements for a new system should provide for draining the entire system.

Radiators

The radiator transfers heat from the hot water in the pipes of a hot-water heating system into the surrounding air in a room. A radiator is usually of two types. Cast-iron radiators are constructed and assembled in sections, as shown in figure 4-68, view A. Damaged radiator sections can be replaced without replacing the entire radiator assembly. Fin-tube radiators (fig. 4-68, view B) are constructed of steel pipe and fins, which are welded to the pipe.

Radiators usually rest on the floor. However, they can be either mounted on a wall or hung from the ceiling. The location of a radiator depends on the type of room to be heated and its location with respect to the location of the boiler. For instance, in a forced-circulation hot-water distribution system, the radiators may be on the same level with the boiler.

Convectors

Convectors are supported on the wall much in the same way as a pipe. The convectors consist of a fin-tube radiator mounted in a metal cabinet and transfer heat much in the same way, although a damaged section must be welded or the entire convector must be replaced (fig. 4-68, view C).

Hot-water heating system radiators and high points in the distribution lines must have some type of vent that releases air from the system. Air trapped in the system prevents the circulation of water. For this purpose, a manually operated key-type air vent, as shown in figure 4-69, can be used.

Manually operated key-type air vents can be replaced by automatic air vents. One type of automatic air vent is shown in figure 4-70. It automatically allows the air that forms in the system to escape. When air vents fail, replace them.

Radiators also have shutoff valves, as shown in figure 4-71, which reduce or stop the flow of hot water through a radiator. They are installed in the piping next to the inlet side of the radiator. Occasionally, you must tighten the packing nut on these valves to prevent the water from leaking around the valve stem.

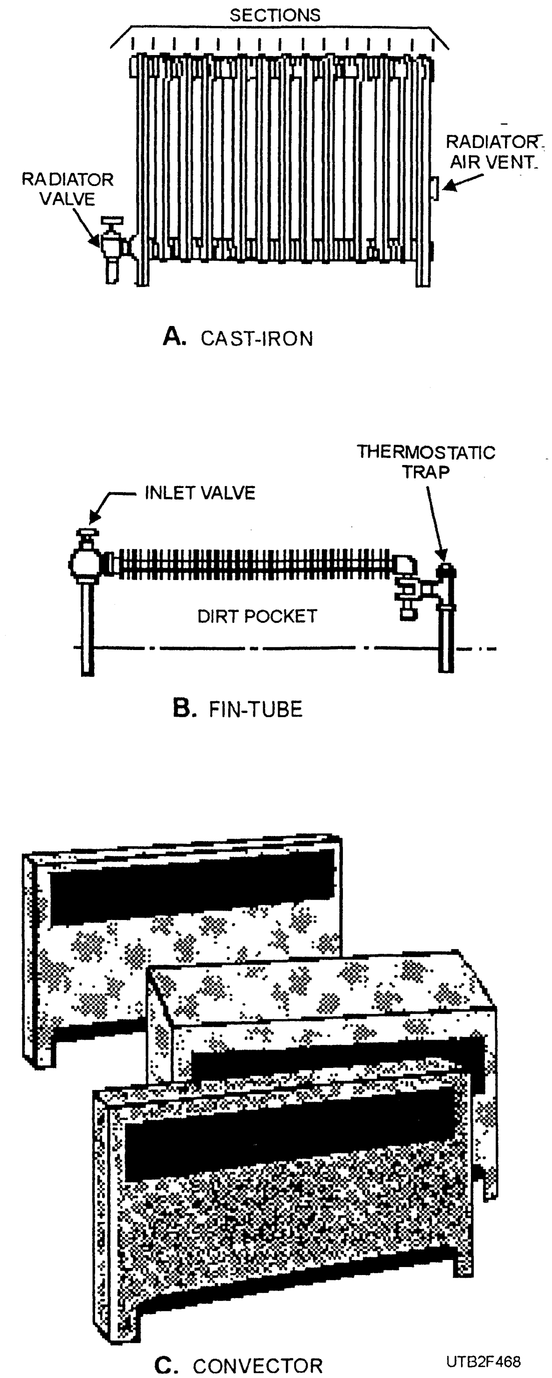

Figure 4-68.—Radiators: A. Cast iron; B. Fin tube; C. Convector.

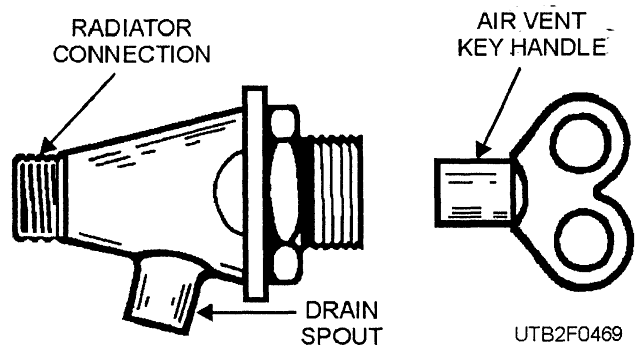

Figure 4-69.—A manually operated key-type air vent.

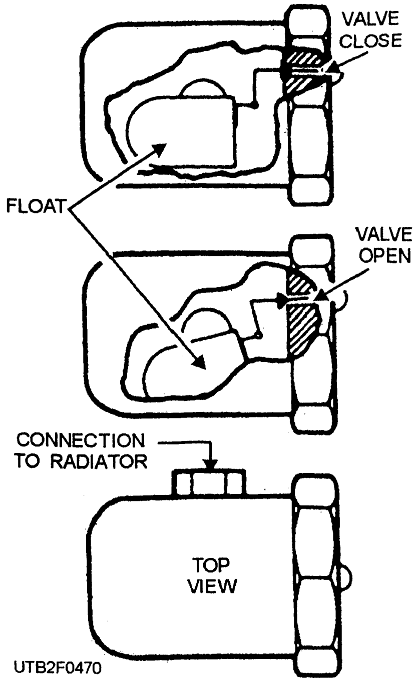

Figure 4-70.—One type of automatic air vent.

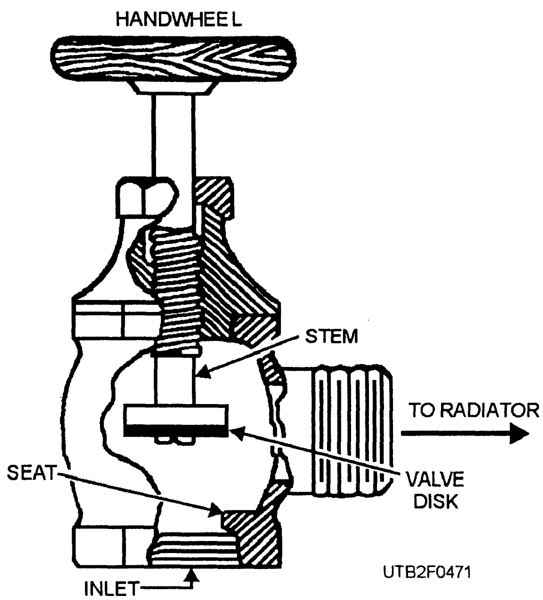

Figure 4-71.—A typical radiator shutoff valve.

Unit Heaters

Unit heaters are the same as those used in warm-air heating, except hot water is used vice coils for the heating medium. The heater consists of a heating coil supplied with hot water. The coil is usually of the finned type, and an electric fan circulates air over it. A unit heater installed in a distribution main is shown in figure 4-72.

Servicing unit heaters includes a monthly inspection. Each month, check for water leaks, cleanliness of the finned coils, and the operation of the fan motor. Other accessories which you also should inspect are traps, air vents, fan blades, and valves. Make any needed repairs. Lubricate the electric fan monthly.

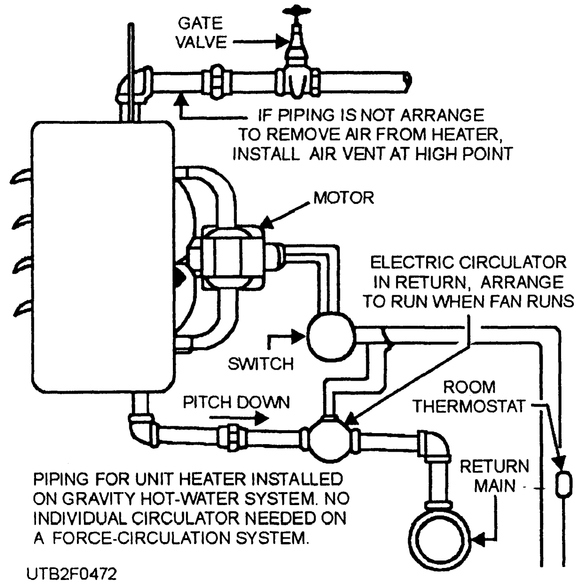

Figure 4-72.—A typical hot-water unit heater installation.

Circulating Pumps

A forced hot-water heating system has a water-circulating pump in the return line near the boiler. This pump ensures the positive flow of water regardless of the height of the system or the drop in the water temperature. Greater velocities of water flow are obtainable with forced circulation than with gravity circulation.

Circulating pumps are free of valves and float control elements. They are operated under a sufficiently high water inlet temperature to eliminate the difficulties caused by vapor binding. The pumps are usually operated by electric motors.

During maintenance servicing, check the pump carefully for proper rotation, and lubricate the electric motor and pump according to the manufacturer's instructions. Also, periodically clean the pump of sand, rust, and other foreign matter that has collected in the pump casing. Be sure the pump rotates freely and the shaft packing glands, if there are any, are not drawn up so tight that they score the shaft.

Reducing Valves

A reducing valve is normally installed in the cold-water line going to the boiler. It automatically keeps the closed system supplied with water at a predetermined safe system pressure. These valves are usually set at the factory, but you may adjust them in the shop to a desired pressure. You should install this valve at approximately the same level as the top of the boiler.

Flow-Control Valves

Forced hot-water circulating systems use the flow-control valve shown in figure 4-73. It is normally installed in the distribution main. This valve prevents gravitational flow of water through the system. The valve does not offer any serious resistance to the flow of water when the circulating pump is in operation. However, when the pump is not operating, the small gravitational head of water cannot open the valve. Each week you should check the flow-control valve for proper operational down-free movement. Examine the valve for water leaks and repair it when necessary.

Special Flow Fittings

Various types of special tees designed to deflect main-line water into the radiator branches are used in one-pipe and two-pipe forced-circulation systems. These fittings are designed and calibrated to the size of the radiator and system-operating temperature. Fittings of this type are required with one-pipe, forced-flow systems, and they do equally well for radiators above and below the distribution mains.

MAINTAINING AND TROUBLESHOOTING HOT-WATER HEATING SYSTEMS

Hot-water heating systems require little maintenance other than periodic checks to make certain that all air is out of the system and all radiators are full of water. The circulating pumps should be oiled regularly according to the manufacturer's instructions, and the pressure-relief valves should be checked periodically.

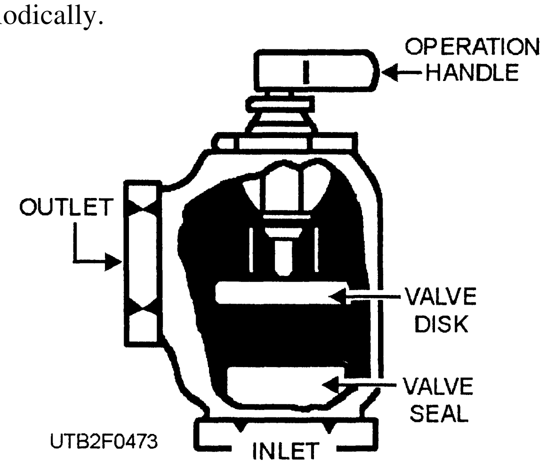

Figure 4-73.—One type of flow-control valve.

Some of the common discrepancies encountered when troubleshooting hot-water heating systems are contained in appendix II, table O.

Operator maintenance on the electrically driven feed pump consists mostly of cleaning the pump and motor. However, the pump motor is lubricated according to the manufacturer's specifications. Remember that not using enough lubricant can result in the bearings running dry or seizing on the motor shaft. But, too much lubricant causes the motor to become dirty, and it can result in the motor windings becoming saturated with oil and burning out.

When a water leak develops around the pump shaft, tighten the packing-gland nuts or repack the stuffing box as necessary. The strainer, installed between the pump and the condensate receiver, should be kept clean to avoid any restriction of the flow of water to the pump.

The maintenance of feed-water heaters and economizers normally includes removing solid matter that accumulates in the unit; stopping steam and water leaks; and repairing inoperative traps, floats, valves, pumps, and other such associated equipment.

Q27. What is the main reason to install a two-pipe, open tank, gravity distribution system over a one-pipe, open-tank, gravity distribution system?

Q28. The operations of what component of the one-pipe, closed-tank distribution system results in higher heat emission from the radiators?

Q29. Air vents release trapped air in the system. If the air is not released, how would this affect the system?

HIGH-TEMPERATURE HOT-WATER SYSTEMS

Learning Objective: Recognize different types of high-temperature hot-water systems, their components, and understand their application and installation.

High-temperature hot-water (HTHW) systems operate at high pressure to maintain water temperature that exceeds the normal boiling temperature of 212°F (at atmospheric pressure) used in other types of heating systems.

High-temperature hot-water systems consist of standard and heavy-duty equipment, including boilers (sometimes referred to as generators), expansion drums, system circulator pumps, distribution piping, and heat-consuming equipment.

High-temperature hot-water systems have the hot water pumped from the generator throughout the distribution system. The circulator pumps are large enough to deliver the water at sufficient pressure to overcome any drop in the distribution system and the heat-consuming equipment. The major advantages of the HTHW heating system are makeup requirements, minimum maintenance, high thermal efficiency, and safe, easy operation and control.

The HTHW system is a closed system, so the only water waste is the normal leakage at the pump and valve packing glands. Consequently, little water is consumed during system operation. This means only a small amount of makeup water is used, practically eliminating boiler blowdowns. The closed re-circulating system operates at high thermal efficiency. All of the heat not used by heat-consuming devices in the system or lost through pipe radiation is returned to the boiler plant. Because few boiler blowdowns are required, the heat loss from blowdowns is kept to a minimum.

TYPES OF HTHW SYSTEMS

The high-temperature range for most military and federal heating plants is 350°F to 450°F which corresponds to saturated pressures of 135 psi to 425 psi. However, some types of plants operate at higher pressures and therefore have higher water temperatures. The installation of HTHW plants that operate at temperatures above 400°F must be approved by the Naval Facilities Engineering Command. Costs usually determine the maximum water temperature used, because the types of HTHW systems using the higher pressures require more expensive piping, valves, fittings, and heat exchangers.

The degree of complexity of HTHW systems varies according to the size, type, and heat load requirement of the installation. Since methods used to maintain pressure and to assure uniform flow rates depend upon the amount of heat load, they affect the complexity of the heating system. There are two methods of circulating the HTHW through the system—the one-pump system and the two-pump system.

The one-pump system uses only one pump to circulate the hot water throughout the system, which includes the generator. The two-pump system uses one pump to circulate the water through the distribution system, and a second pump to circulate the water through the generator for positive circulation. Figure 4-74 shows some typical pumps that are used for circulation in the HTHW system. Note that the pumps are of the centrifugal type. Each pump shown is used to circulate the water to different areas in the distribution systems.

There are two common ways of heating the water in the HTHW system—one way is to use hot-water boilers or generators and the other way is to use the cascade or direct contact heater. The water in the HTHW generator is heated as low-temperature hot water is heated. In the cascade heater, however, the water is forced through spray nozzles and comes into direct contact with the steam. The steam condenses into the circulating water. A typical spray nozzle head is shown in figure 4-75. The spray nozzles are installed in a combination cascade heater expansion drum. A typical cascade heater expansion drum installation is shown in figure 4-76. In the paragraphs that follow, some ways of pressurizing the HTHW system are discussed.

PRESSURIZING THE HTHW SYSTEM

Since water volume varies with changes in temperature, the extra water must be taken care of when the water is heated. It is desirable to operate with the water above the boiling temperature of 212°F; therefore, the pressure in the system must be maintained equal to, or greater than, the corresponding saturation (steam or vaporization) temperature. An expansion tank is required because the water, which is not compressible to a smaller volume, expands when it is heated. Also, the pressurization prevents the formation of saturated steam or vaporization when the water temperature is raised. There are two basic designs used for pressurizing HTHW systems—first, the saturated steam cushion, and second, the mechanical gas cushion. Although both des igns have a variety of modifications, their characteristics are still typical of the basic pressurized system design.

Saturated Steam Cushion

Pressurizing the heating system with steam in the expansion tank is a natural method. Firing the HTHW generator to maintain the system pressure corresponding to the required saturation (steam or vaporization) temperature pressurizes the system. Excess heat is generated to offset the radiant heat loss from the expansion tank. All of the HTHW in the steam-pressurized system flows through the expansion tank and thereby maintains the saturation (steam or vaporization) temperature there.

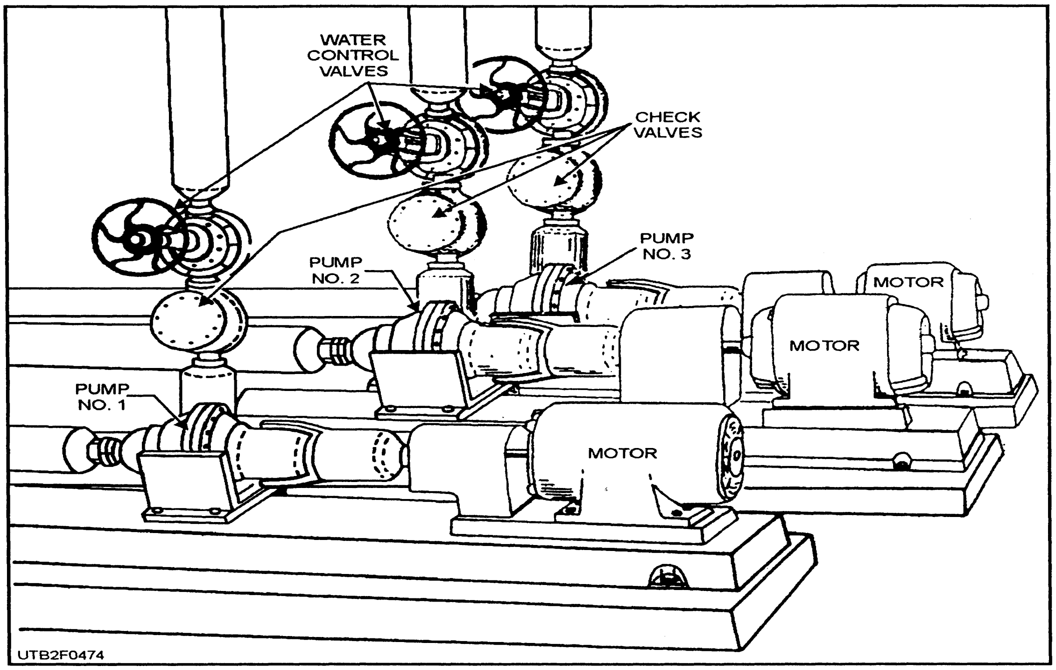

Figure 4-74.—Typical high-temperature hot-water circulation pumps.

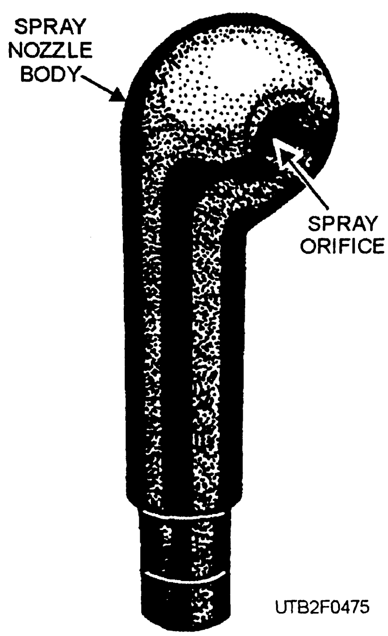

Figure 4-75.—A typical cascade heater spray nozzle head.

The steam in the space in the expansion tank provides the pressure or cushion for the system. The pressure maintained is that of the saturated steam. The water in the lower portion of the tank will be approximately saturation (steam or vaporization) temperature corresponding to this pressure. The water to be used in the HTHW heating system is drawn from the lower part of the expansion tank, mixed with the system return water, and circulated throughout the system. The mixing is necessary to prevent cavitation (steam flashing) at the pump suction.

Here are some conditions that are typical of the saturated-steam cushion design. The expansion tank, either integral or separate, is a part of the HTHW system. The entire amount of hot water flowing in the heating system passes through the expansion tank and exposes the tank to maximum system heat and any form of contamination which, in turn, subjects the expansion tank to thermal stresses and corrosion. There are explosion hazards typical of a steam boiler in the system, and good water-level control is important in maintaining proper operating conditions. Load variations, causing supply pressure changes, create flashing of saturated liquid in the system and produce water hammer.

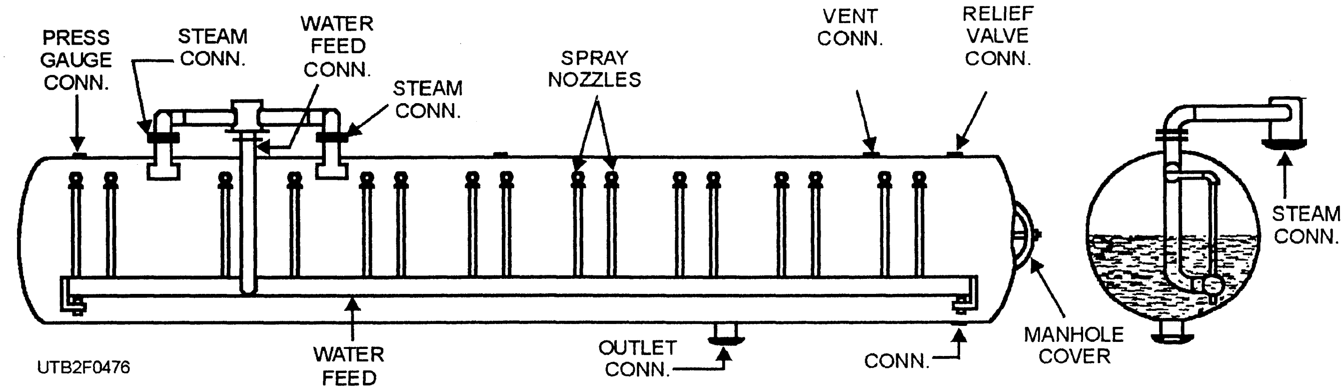

Figure 4-76.—A combination cascade heater expansion drum installation.

Mechanical Gas Cushion

The expansion tank contains the mechanical-gas cushion and is connected to the HTHW system return line just ahead of the circulating pump suction connection. The tank contains an inert gas (usually nitrogen) and is the source of pressure in this method. When the system has been pressurized by the nitrogen, pressure in excess of saturation must be maintained; that is, the water temperature throughout the system must always be less than its saturation temperature. In the nitrogen-pressurized system, the expansion tank is installed in the system as a standpipe arrangement so the water does not flow through it. The water in the lower part of this tank is stagnant, except for the changes caused by expansion and contraction brought on by load fluctuations. If you assume the water is virtually incompressible, the tank provides the space available for these changes in the water volume of the system.

Here are some characteristics that are typical of this design. The expansion tank is independent of the generator and remains cool. Corrosion is practically eliminated because the heating system is flooded with the exception of the nitrogen space in the expansion (cushion) tank. When properly designed, the system is sealed with its fixed charge of water and nitrogen. However, this design does not contain a steam drum or any steam spaces that permit the accumulation of steam. The generator tubes are the weakest link in this entire system. An explosion caused by the dissociation of hydrogen and oxygen cannot occur. The formation of steam cools the otherwise red-hot metal surfaces. Hot-water conditions do not allow the flashing of steam.

Operation

To ensure normal operation, fill the system with treated water taken from the water softener. To prevent oxygen corrosion, add the chemicals for treating the water to furnish 20 to 40 parts of sodium sulfite per million parts (ppm) of water. You thereby maintain a pH value of 9.3 to 9.9. While the water is circulating in the generator and in the system, you should fire the boiler at about 25 percent of its rated capacity to bring the system up to normal operating temperature. You should allow the expansion drum vent in steam-pressurized systems to blow for about 1 hour to rid the system of all oxygen and other non-condensable gases.

The start-up and firing of HTHW boilers or generators arc done in much the same manner as for domestic hot water and steam boilers, depending upon the type of fuel-burning equipment used. The specific start-up and operating procedures vary with different installations. Therefore, this information is furnished by your local supervisor and the manufacturer of the equipment.

Coal, oil, and gas are the types of fuels normally used to fire the boilers of HTHW systems. The specific type of fuel used depends upon the type of firing equipment installed in the plant. Each type of fuel requires designated inspections be made -and certain precautions be taken to eliminate fire and safety hazards.

When you are transferring fuel oil from one tank to another, be sure both tanks are grounded. Checks must then be made to ensure excessive oil pressures are not generated in the tanks by the expansion of the fuel. Although natural gas is not normally stored on a base ashore, liquid petroleum (LP) gas is often stored near the heating plant. You should check the areas where this gas is stored often to ensure there is no leakage. Liquid petroleum gas is heavier than air, settles in low areas, and creates explosive hazards. When checking for gas leaks, use a standard soap solution.

Because of the large heat storage capacity of HTHW systems, the load demand change for the boiler is slow and smooth. This characteristic provides for improved and safer operation than that provided by the saturated-steam cushion.

PIPING SYSTEM INSTALLATION

All piping in an HTHW system should be welded. No screwed joints should be permitted, and flanges should be allowed only where necessary, such as at expansion joints, pumps, and generator connections. Only schedule 40 black steel piping or better is used for HTHW systems. Upon completion, the entire heating system is subjected to a test of 450 psi that lasts for not less than 24 hours.

The possibilities of line failure are remote when the construction recommended above is used. The system piping material is subjected to a minimum factory test of 700 psi. The generator tubes are subjected to an ASME test of 900 psi. All valves and accessories are rated at working pressures of 540 to 1,075 psi at 400°F. The weakest link in the piping network lies within the generator tubing. The worst likely failure is the loss of tubes, and therefore the generator. The safety of the piping system is maintained over the life of the installation because of the absence of corrosion in the hot-water heating systems due to boiler water treatment.

Q30. What is the high-temperature range for most military and federal heating plants?

Q31. What are the two common ways of heating water in HTHW systems?

Q32. To prevent oxygen corrosion in an HTHW system, treat the water with chemicals to produce whatppm of sodium sulfite?

Q33. Should all piping in an HTHW system be welded? True/False